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APRIL, 1937

CUSTER FORMATION OF TEXAS[1]

ROBERT ROTH[2]
Wichita Falls, Texas

ABSTRACT

The field work and detailed mapping which form the basis of this paper are a continuation of previous work done in the general area. The trace of the unconformity at the base of the Custer is shown in detail by a series of county maps. Also one general map shows the change in direction of the trace of the unconformity and the trace of the base of the San Angelo. The length of the area covered by this field work is 300 miles, from Wheeler County, Texas, southward to Coke County, Texas.

Many changes of facies were observed in the field and these have had an important bearing upon the nomenclature as the beds were traced southward from Kansas and Oklahoma into Texas. Because of the loose application of the nomenclature of Kansas and northern Oklahoma to beds in Texas which are only partially equivalent, the writer has quoted the original type descriptions so that the differences may be apparent at once. It is to be hoped that the naming of facies as a formation and the bounding of these formations by chemical deposits will not be perpetuated as only confusion can result from this practice. This method of nomenclature has been and is now widely used, especially in Texas. It is again suggested that the beds occupying the interval between the base of the Dockum and the unconformity mapped be given one formation name, Custer, and the names now in usage be confined to the facies which they represent.

A brief discussion of the field evidence for the alteration of anhydrite to gypsum, and the effect of this hydration upon the inclosing sediments is presented. The lithologic difference between the anhydrites of the Custer and the gypsums of the Blaine is included.

Some unusual problems of erosion now active in this part of Texas are discussed. Due to the presence of wind-blown sand and the escarpment of the Great Plains little is known concerning the stratigraphy of the upper part of the Custer.

Certain physiographic features observed in the field are described, such as karst topography and results of epicycles of erosion. The solution of the gypsum and salt in the Blaine has resulted in the formation of the erratic dips observed in the lower Custer. The exposed part of the Blaine now presents a beautiful example of karst topography. Two epicycles of erosion are now in active process, and badlands are being formed in the older rolling topography.

INTRODUCTION

During the spring and early summer of 1934 reconnaissance studies were made of Childress and Collingsworth counties, Texas. In

[1] Read before the Association at Tulsa, March 19, 1936. Manuscript received, January 15, 1937.

[2] Humble Oil and Refining Company.

the course of this work it was found that the base of the Custer, as previously described by the writer,[3] was incorrectly drawn in parts of the area. In that paper the base of the Dozier Mounds dolomite was chosen as the base of the Custer, because the Dozier Mounds dolomite and the Verden Channel dolomite of Oklahoma were considered as being the same. This is incorrect. In Stonewall County, Texas, the base of the Custer was drawn just above the shales which overlie the Croton gypsum. This is also incorrect. As a result of these errors it was deemed advisable to map accurately the base of the Custer where it first enters the Panhandle of Texas from Oklahoma, and thence southward as far as possible or until it is overlapped by the Comanche and Tertiary rocks. The amount of time required for the necessary field work was greatly extended due to the fact that early in 1935 the whole Great Plains area was subjected to very severe dust storms. For many days at a time visibility was reduced to less than ¼ mile. The most exasperating thing was the deposit of gray dust left over the country side. This deposit completely masked the color change which is of so much help in separating the Custer from the older formations.

As a result of this field work it has been found that in Collingsworth and Wheeler counties the contact between the base of the Custer and older beds is one of sandstone resting on shale or gypsum. In Childress and Cottle counties the Childress dolomite is 3–20 feet above the base of the Custer. In King and Stonewall counties, the base is sandstone on shale or gypsum. Locally there are anhydrite beds just above the basal sandstone. In Fisher, Nolan, and Coke counties, the base is marked by sandstone or anhydrite and a fine quartz conglomerate. In these three counties, the position of the Eskota dolomite ranges from a few feet to 20 feet above the base. The sediments below are shales, sandstones or gypsum of the "Blaine of Texas." However, in Nolan and Coke counties the pre-Custer erosion has removed almost all of the "Blaine of Texas" and the Custer rests on the upper sandstone facies of the San Angelo.

As the lithologic differences between the Custer and the underlying formations were adequately described in the afore-mentioned publication, they are not described here.

It has been found that the term Whitehorse is very loosely applied to the sediments of Custer age in Texas. The same difficulty applies to the usage of the terms "Cloud Chief" and "Quartermaster." The boundaries of all are very vague, and there is not only the "Blaine of

[3] R. Roth, "Evidence Indicating the Limits of Triassic in Kansas, Oklahoma and Texas," *Jour. Geol.*, Vol. 40, No. 8 (November-December, 1932).

Texas," but also a "Whitehorse of Texas," *et cetera*. Such a state of nomenclature can lead only to confusion. In an endeavor to clarify the matter, the writer has gone back to the original definitions so that some line of logic may be followed in Texas.

PROBLEM OF WHITEHORSE NOMENCLATURE AND CORRELATION

Probably no beds in the Mid-Continent are as vaguely understood as those related to the Whitehorse facies. The writer has questioned many fellow-workers concerning the local definition of the Whitehorse. As a result of these inquiries, it is evident that the Whitehorse is delimited only near its type locality in southern Kansas and northern Oklahoma. From this area southward a tripartite system of nomenclature is in general use. This system recognizes the Whitehorse at the base, the Cloud Chief next, and the Quartermaster as the highest bed. On paper it seems to be a very simple classification.

Before judgment is passed on the simplicity of the problem let us look back and consider just what was described as being part of the formations as named at the type localities. Since the publications with these descriptions are now out of print and are to be found only in libraries, somewhat lengthy quotations are used. F. W. Cragin[4] first described and delimited to a certain extent the beds which are here considered. Cragin's classification of the Cimarron series is as follows.

CIMARRON SERIES

Divisions	*Formations*
Kiger	Big Basin sandstone*
	Hackberry shales*
	Day Creek dolomite
	Red Bluff sandstones
	Dog Creek shales
Salt Fork	Cave Creek gypsums
	Flower-pot shales
	Cedar Hills sandstones
	Salt Plain measures
	Harper sandstones

Cragin makes this note [p. 3]: "The Day Creek and the Big Basin are the only formations of the Kansas Permian that seem to be absolutely simple terranes, or to consist each of a single bed."

The Kiger division upon which our interest is centered is described as follows [p. 39].

The upper division of the Cimarron series is the Kiger division, so named from Kiger Creek in Clark County, Kansas, a stream that traverses all of the terranes of this division except the lowest.

Dog Creek shales [pp. 39–40].—

The lowest member, or Dog Creek terrane, of the Kiger consists of some thirty feet, or locally of a less or greater thickness, of dull-red argillaceous

[4] F. W. Cragin, "The Permian System in Kansas," *Colorado College Studies* (Colorado Springs, Colorado), Vol. 6 (March, 1896), pp. 3–48. Page numbers in brackets in the following paragraphs refer to Cragin.

shales, with laminae of gypsum in the basal part and one or two ledges of unevenly lithified dolomite in the upper part. The color of these shales resembles that which prevails in most of the terranes of the Salt Fork division below, more than that of the Kiger terranes above the Dog Creek. The dolomite varies from light-gray to dark-gray, and clay-impregnated portions may partake of the red color of the including shales. In lithological character, it varies from solid stone . . . to that which is so contaminated with clay as to be soft or worthless. It is often cellular or cancellated.

The type locality is south of Lake City on Dog Creek, Barber County, Kansas.

Cragin recognized that though beds of the Kiger bore certain general resemblances to those of the Salt Fork division, in the main they present a different aspect. This prevailing difference is specially due to the thick body of bright red rocks which constitute the major part of Kiger sedimentation which Cragin named the Red Bluff beds [pp. 40–43].

This formation consists of some 175 or 200 feet of light red sandstones and shales. . . . Viewed as a whole, it is very irregularly stratified, the component beds, while consisting of nearly parallel laminae, being in some cases considerably inclined, in others, curved, and this oblique and irregular bedding, being on a much larger scale than that of ordinary crossbedding, at first glance gives the impression of dips, anticlines and synclines that have been produced by lateral pressure, the dips being, however, in various directions. . . .

Cragin believes that this latter phenomenon is due in part to the conditions under which the sediments were originally laid down.

The Red Bluff beds exhibit the most intense coloration of any of the rocks of the Cimarron series, being approached in this respect only by the Cedar Hills sandstones. When the outcrops are wet with recent rains, their vividness of color is still greater, and the contrasts of their almost vermillion redness with the other colors of the landscape is most striking. Spots and streaks of bluish or greenish-gray sometimes occur in the red of these rocks, but not to nearly the same extent as in the Salt Fork Division. . . . A marked characteristic of most of these sandstones is their unusually fine texture. When pulverized, or as seen in soils that have been derived from them, they sometimes seem like brick-dust. So light are some of their soils that, walking over them, one may sink shoe-deep, as if walking on the mellow ground of a well cultivated field. The sandstones are also porous and, especially when overlain not far away by Neocene sands, are often a source of water. . . . The shales of the Red Bluff are rarely without some admixture of fine arenaceous matter. The Red Bluff beds, once uncovered, yield rapidly to subaërial erosion and their outcrops generally show a rugged, canyon-cut relief which, in connection with their bright-red color and their frequent setting-off with dark green cedars, makes some of their landscapes exceedingly picturesque. The sandstones are frequently trimmed off by stream-erosion in a long, straight, vertical wall that resembles the face of a quarry.

The type locality is on Bluff Creek above Protection, Comanche County, Kansas, where the "Red Bluff" which gave name to the former post office of Red Bluff is located.

Day Creek dolomite [pp. 44–45].—

Upon the latest of the Red Bluff beds rests a persistent stratum of dolomite, varying from less than a foot to five feet or more in thickness. The stone is nearly white in fresh fracture, weathers gray, and often has a streaked and gnarly grain crudely resembling that of fossil wood. It is more cellular and in places cancellated. Irregular nodules of limonite are here and there imbedded in it. Its cherty hardness and fracture are not due to the presence of silica, as one is tempted to infer, but are characters belonging to it as a dolomite. . . . [Locally the Day Creek stratum] becomes a homogeneous, semi-translucent white rock of remarkably pure aspect, unlike any other rock with which the writer is acquainted, but bearing more or less resemblance to fine-grained marble, or to onyx or chalcedony.

Cragin proposes to call this peculiar variation of the Day Creek dolomite, Faresite. The type locality of the Day Creek dolomite is at the head of Day Creek in Clark County, Kansas.

Hackberry shales [p. 46].—

In Clark County, Kansas, the Day Creek dolomite is overlain by 15 to 20 feet of crumbling, chiefly maroon-colored shales, including some moderately hard laminae that in weathering check into small cakes and dice-like chips. They are well shown in the region of the junction of Hackberry and Bluff creeks, from the former of which they derive the name Hackberry shales.

Big Basin sandstone [pp. 46–47].—

The western, northern and northeastern parts of the bluffy walls of Big Basin are formed largely by the calcareous sandstone of the Loup Fork; but on the easterly to southeasterly quarter the rim of the basin is chiefly of Kiger sediments, in which the Hackberry shales appear with a coping of rather massive, blocky, red and grayish-white sandstone. The latter, from this locality of its typical occurrence, may appropriately be known as the Big Basin sandstone. . . . Its maximum thickness probably does not anywhere exceed 12 feet. While particolored, it has less of the poikilitic character than is seen in most of the particolored rocks of the Cimarron series, the two colors being arranged in two (locally three) broad bands, of which one is almost uniformly red, and one almost uniformly grayish-white with occasional flecks of red. At one locality on the eastern rim of the Big Basin, where it is overlaid by, and not abruptly separated from an incoherent sandstone of the lower Cretaceous, the Big Basin sandstone is clearly also the highest surviving terrane of the Cimarron series, and therefore of the Permian, if all of the Cimarron series be really of Permian age as here assumed.

This concludes quotations from the first scientific treatise of the upper red-beds of Kansas. As a field classification Cragin's work is easy to follow, largely because the area in which the rocks crop out is very small, and the effect of lateral transition can not be observed in a few square miles.

Following the foregoing work, Cragin had occasion, in September of the same year (1896), to make further studies of the Cimarron series in Oklahoma. It is of interest to note that Cragin at once realized certain difficulties when he applied the nomenclature he had used in Kansas to equivalent beds in Oklahoma. These difficulties were of such a nature that explanations were deemed necessary and were incorporated in a short paper.[5] Cragin [pp. 352–53] wishes to transfer the Dog Creek shales from the Kiger to the Salt Fork division for the following reasons.

> Because, from Kansas southward to the Stoney hills of Blaine County, Oklahoma, and to an unknown distance beyond, the line between the Dog Creek and the higher formations is sufficiently well distinguished and the danger of confusing this formation with any other dolomite formation is eliminated by its constant association with the Cave Creek gypsum formation, and finally because (as stated in "The Permian System in Kansas") the red shales of the Dog Creek agree better in lithological character and color with those of the Salt Fork division below the Cave Creek than with those which are most characteristic of the Kiger division, and often contain, in their lowest part, seams of gypsum similar to those in the horizon next below the Medicine Lodge gypsum (viz., the Flower-pot horizon of the Glass Mountain formation), I am now led to transfer the Dog Creek formation from the Kiger to the Salt Fork division, placing the line between the two divisions where, in preparing my earlier paper above cited, I suspected that it should be drawn, viz., at the summit of the Dog Creek formation.

Cragin did not recognize the presence of an unconformity separating the two divisions, but he did recognize the profound change in lithologic character between the Salt Fork and the Kiger. It is of interest that Cragin [p. 356] described something which Gould later overlooked—the Cave Creek formation as that horizon of gypsum beds which was later called the Blaine in Kansas, Oklahoma, and Texas. Cragin considered the Cave Creek formation as being tripartite in character, especially in southern Kansas and northern Oklahoma. He described the formation as forming the Marcy Range, trending southeastward into central Oklahoma. The Cave Creek was identified by him in Washita and Roger Mills counties of western Oklahoma. Following the outcrop around the western end of the Wichita Mountains, Cragin traced the formation into Texas where he believed it to extend southward for an unknown distance. As many localities were mentioned by name there is no doubt that the anhydrites of what is herein called the Custer were not included by Cragin in the Cave Creek in Texas, later known as the "Blaine of Texas."

[5] F. W. Cragin, "Correspondence," *American Geologist*, Vol. 19, No. 5 (May, 1897), pp. 351–63. Page numbers in brackets in the following paragraphs refer to Cragin.

Cragin [p. 359] describes some gypsum horizons of the Kiger which crop out in Beaver County, Oklahoma. Among other statements the following is pertinent.

The gypsum horizon seen on Clear Creek is now known to be well up in the Kiger division and, from its occurrence near Beaver City and in the county and river-basin of Beaver, I propose to call it the Beaver gypsum.

This was only one of the many new names proposed by Cragin and more were introduced later when the various beds of anhydrite, occurring in the Custer, were encountered farther south in Oklahoma.

In discussing the Red Bluff formation as seen in Oklahoma near Watonga, very few lithologic differences were noted when the formation was compared with the type locality in Kansas. Manifestations of salt were seen as efflorescence on rocks in stream beds.

In discussing the Day Creek dolomite, Cragin says [p. 361]:

In the western part of Clark and in Meade Counties, Kansas, the Day Creek formation loses its typical character. It is there represented by a band of greenish-gray to red and gray sandstone with occasional streaks of dolomite.

Farther on though, Cragin states he found no connecting outcrops.

The brow of the Red hills near Watonga, Oklahoma, is capped with the Day Creek dolomite, which there presents itself as a compact stratum of gray, somewhat pinkish or reddish-tinged, cherty-hard rock, little different from the typical ledge that skirts the flanks of Mount Lookout in Clark County, Kansas. The stratum has a thickness of three feet.

In discussing those beds which occur above the Day Creek formation as drawn by Cragin, he introduces three new names, as follows [pp. 362–63].

The persistence of typical Hackberry shale and Big Basin sandstone in central Oklahoma is at least doubtful, while observations made southwest of Watonga and on the South Canadian river, in D.[6] County, reveal a great thickness of Kiger rocks above the Day Creek dolomite, in this part of Oklahoma. For this reason a three-fold parting of the Kiger division seems to be the only practicable one, if we restrict this division to Cimarron rocks higher than the Dog Creek. Thus the formations of the Kiger division would be: the lowest, or Red Bluff; the middle, or Day Creek; and the highest, or Taloga; the latter named after the town of Taloga, county seat of D. County, Oklahoma, being here proposed to include all of the Kiger rocks above the Day Creek. . . . In west-central Oklahoma, some of the red rocks of the Taloga present a remarkable resemblance to those of the Red Bluff formation which are seen in the northeastern part of Barber County, Kansas, having the same texture and intensely red color and giving rise to the same peculiar soft and loamy and "brick-dust" soils which there characterize the latter formation. Only two horizons of the Taloga observed in that part of Oklahoma need

[6] D. County, Oklahoma, is now known as Dewey County.

> here be especially designated. These are both of gypsum of poor quality, and belong to the bluffs that rise on the south side of the Canadian River, in D. County, in view from the postoffice of Butte. One of these appears in the brow of the bluffs, . . . and has a thickness of 3 or 4 feet. The other, much more limited in horizontal extent, occupies a position 90 or 200 feet lower, and has a thickness of only a foot or two, but is underlain with 4 or 5 feet of red gypsum-clay. They may be called respectively the One Horse and the Old Crow gypsum after the two fords of the Canadian river which (after the Indians resident near them) are known as the "One Horse crossing" and the "Old Crow crossing," the upper bed being named from the upper ford—One Horse, and the lower from the lower.

Cragin recognized and so states that these gypsum beds are not continuous, but represent a general stratigraphic level.

Cragin's classification of the upper part of the Cimarron series is as follows.

Division	*Formation*	*Subformation*
Kiger	Taloga	Quite variable with locality
	Day Creek	None
	Red Bluff	None determined

Thus ends the first series of formation names proposed for a depositional unit with which future geologists must contend. Cragin has left many loose ends which are now more or less obvious. Some of the difficulties will be taken up after a discussion of the paper by Gould.[7] In this paper Gould uses the following classification and the reasons for it [p. 39].

RELATIONS OF CLASSIFICATIONS OF PERMIAN ROCKS

Cragin's Classification	*Gould's Classification*	
	Quartermaster formation	
Taloga	Greer formation	Mangum dolomite member Collingsworth gypsum member Cedartop gypsum member Haystack gypsum member Kiser gypsum member Chaney gypsum member
Day Creek Red Bluff Dog Creek (Stoney Hills)	Woodward formation	Day Creek dolomite member Whitehorse sandstone member Dog Creek shales member
Cave Creek	Blaine formation	Shimer gypsum member Medicine Lodge gypsum member Ferguson gypsum member
Glass Mountain Kingfisher	Enid formation	

Blaine formation [pp. 44–45].—Gould describes the Blaine formation as follows.

> The Blaine formation consists of red shales with interbedded strata of gypsum and thin ledges of dolomite. It includes the portion of Professor

[7] C. N. Gould, "Geology and Water Resources of Oklahoma," *U. S. Geol. Survey Water Supply and Irrigation Paper* 148 (1905). Page numbers in brackets in the following paragraphs refer to Gould.

Cragin's Flowerpot formation above the base of the Ferguson gypsum and all of his Cave Creek formation. It is named from Blaine County, Oklahoma, where it is typically developed. The characteristic which justifies its recognition as a formation is the abundance of gypsum contained in it, and its extent and limits are defined accordingly. The bottom of the lowest massive gypsum bed—the Ferguson gypsum member—is the base of the formation throughout its occurrence northwest from Darlington, Canadian County. Where it disappears the shales of the Enid continue up to the base of the Medicine Lodge gypsum member, which necessarily becomes the basal member of the formation. The top is the Shimer gypsum member. Where the gypsum members run out, as they all do north of Darlington, the Blaine can not be distinguished readily from the Enid below and the Woodward above, and this local division of the red beds can not well be traced.

Woodward formation [p. 52].—

Above the Blaine is approximately 300 feet of rocks, consisting chiefly of shales, sandstones and dolomites, and distinguished from the formations above and below by the prominence of dolomites and the absence of gypsum. The formation includes all of the rocks between the two conspicuous gypsum horizons, the Blaine and the Greer, and in general it may be divided into three members—the Dog Creek, the Whitehorse, and the Day Creek—which were all recognized and named by Professor Cragin from localities in Kansas, except that his Red Bluff was preoccupied, and for it the name Whitehorse has been substituted. For the formation as a whole, from the top of the Shimer gypsum to the base of the Chaney gypsum, the name Woodward is proposed, from the county in Oklahoma where the strata are well represented.

No lithologic description is given of the Whitehorse member, except that in many places it weathers into conspicuous buttes and mesas. The type locality is given as Whitehorse Springs, Woods County, Oklahoma. No thickness of the Whitehorse is given except by inference, *viz.*, the Woodward is 300 feet plus or minus, and the thickness of the Dog Creek is 150–225 feet.

Greer formation [p. 59].—

Above the Woodward formation are red clays, shales and sandstones, and intercalated beds of gypsum and magnesium limestone or dolomite 150 to 300 feet thick. Gypsum is the characteristic deposit of this formation, as it is of the Blaine. This formation, for which the name Greer is proposed, from the county in southwestern Oklahoma, in which it is well exhibited, is exposed over a very irregular area. For the purposes of discussion it may be grouped according to two general areas, an eastern and a western. . . . The rocks of these two areas are overlain by the same formation.[Since the rocks of the western area of the Greer have been proved to be the equivalent of the Blaine a discussion of them is not necessary here.]

The rocks of the eastern area of the Greer formation strike northwest and southeast just west of the outcrops of the Woodward formation. They are chiefly red clay shales, interstratified at several horizons with red sandstones and gypsums, which are, however, very irregularly bedded and can rarely be traced as continuous or definite ledges. Nevertheless, the thickest ledges

of gypsum known in the red beds are found in this area. [Sixty feet is the maximum described by Gould.] But these beds are not constant, thickening rapidly or disappearing without apparent regularity. Along a single bluff one may see the beds change from gypsum to sandstone within a distance of a few rods, and a quarter of a mile farther the sandstone again merges into gypsum. So variable is the stratification of all the rocks of the Greer formation in this region that no attempt is made to divide it into members. A section would usually not answer for a point half a mile away.

In the field Gould recognized the "One Horse" and "Old Crow" gypsums, though he does not use these names. These two beds are traced directly into the Greer of the eastern area. It will be noticed that Cragin considered the western Greer as the Cave Creek.

Quartermaster formation [p. 72.]—

Above the Greer are 300 feet or more of soft, red sandstones and arenaceous clays and shales, to which the name Quartermaster has been applied. . . . In the lower part of the formation the rocks are chiefly shales, typically red, but sometimes containing greenish bands and layers. The shales become more arenaceous above, and in places form a strong, consolidated sandstone, which is rather thin bedded and prone to break into small rectangular blocks, and weather queerly into long and narrow buttresses or rounded, conical, or nipple-shaped mounds from 10 to 50 feet or more high. . . . The sandstone is further characterized by the marked and very peculiar dip of the rocks in certain directions. The strata often dip at angles of from 20 to 40 degrees to all points of the compass in a small area.

Gould considered these peculiar dips as being formed by the undermining of deep-seated rocks, such as the gypsum of the Greer, *et cetera*. The type locality is Quartermaster Creek, which has it source in Day County, Oklahoma, and flows into the Washita River. This part of Day County is now Roger Mills County.

The foregoing works by Cragin and Gould have laid the ground work for all later work in the red beds of Kansas and Oklahoma, and since many wish to extend their nomenclature into Texas, a clear understanding of what was meant by the names chosen in the writings of the two men is imperative. First of all, one is struck by the fact that whether a new name is a formation or a member, it is set off from the others by boundaries based on chemical content of the sediments. Anhydrite, gypsum, and dolomite are chemical deposits in the beds considered. A small part of the dolomite of the Blaine may be organic, but it is of minor importance. If divisions had been drawn on the basis of mechanical characteristics, then our present state of uncertainty would not exist.

At the present time the names, Whitehorse, Cloud Chief, and Quartermaster formations are in general use in the Mid-Continent, though what they mean is extremely vague. Before going into the

discussion of the validity of these formation names let us see what is the generally accepted usage of the term, "formation." In trying to find a definition of the word, "formation," the writer found that there are almost as many definitions of it as there are writers. Because of this the United States Geological Survey was consulted and the following definition is quoted:[8] "The fundamental unit in the local classification of rocks." Since this is far from being decisive Bassler prefers to describe a formation as follows:

> The series of strata of more or less the same kind deposited in the same oceanic or other area during a period of geological time in which there were no great changes either in the life or in the distribution of land and water.

With this definition in mind let us look at the first paper by Cragin. Field evidence in southwestern Kansas shows that his original descriptions hold up very well and the formations may be readily identified. The area is small; hence there is little chance for lateral facies to develop.

In Cragin's second paper, difficulties at once arise and he partially recognized them. The mechanical separation of the Red Bluff from the Dog Creek was recognized with the consequent restriction of the Kiger division. The Day Creek was found to be discontinuous. A local dolomite at Greenfield, Oklahoma, was considered to be the Day Creek by Cragin. The belief is now held by many that the Day Creek occurs about 20 miles farther west and is approximately 250 feet stratigraphically above the dolomites at Greenfield. Cragin recognized that the beds above the so-called Day Creek are remarkably similar to the Red Bluff beds. As the presence of the Big Basin and Hackberry could not be established, a new formation, the Taloga, was created. Its principal use is to take care of what remains of the stratigraphic section above the Day Creek after the section is traced from Kansas into Oklahoma. The basis of separation between the Red Bluff and the Taloga, represented by the Day Creek dolomite, is a chemical one. When the Day Creek becomes lost, as it soon does southward into Oklahoma, it is impossible to distinguish where one begins and the other ends.

In Gould's work the difference in the environment, as expressed by the change of sediments between the Whitehorse and the Dog Creek, was not recognized. The Dog Creek, Whitehorse, and Day Creek were reduced to members of the Woodward formation. Gould recognized that the Red Bluff as a bed was preoccupied, and the name Whitehorse was substituted. The type locality was chosen as White-

[8] R. S. Bassler, personal communication.

horse Springs. As no section was described, it is not known what was meant to be included. At the foregoing locality there is a prominent calcareous channel deposit which is fossiliferous. This is included in beds referred to the Whitehorse, but is not present at the type locality at Red Bluff. In this connection the writer has consulted the United States Geological Survey and T. W. Stanton writes:[9]

When a preoccupied name is replaced by another name, the original type section should remain the type section of the unit, unless subsequent work should prove that the section, as well as the name, is poorly chosen, and not the best place to study the unit. In any event the type locality chosen for the substituted name must also be given. In view of the increasing scarcity of geographic names it is frequently necessary to select a name that does not afford the best type section. In this case it is desirable to state that, although the exposures at or near the geographic feature supplying the name are chosen as the type locality, a better place in which to study the unit is at some other described locality.

Gould gave no reasons for changing the type locality or for reducing Cragin's Red Bluff formation to a member of the Woodward formation. As a result of this work, the Whitehorse formation, as it is now generally used, is not as exact a unit as Cragin's Red Bluff.

A most unfortunate circumstance arose when Gould named the Greer formation. The Greer was divided into an eastern and a western area. The difficulty arises from the fact that the eastern area of the Greer is the same as Cragin's "One Horse" and "Old Crow" gypsum horizons. Gould made no mention of these names, although he later chose the area near Cloud Chief, which includes these gypsum horizons, as the type locality of the Cloud Chief formation.[10] Gould mentions the fact that no measured section of the eastern area of the Greer would hold for more than $\frac{1}{4}$ mile, and even in less distance changes are noticeable. With no type section possible it is surprising how long the term Cloud Chief formation has persisted in the literature.

The western area of the Greer is now known as the Blaine, or still earlier, as the Cave Creek of Cragin, who recognized its presence in this part of Oklahoma. This by no means ends the difficulties of the western Greer. In the Panhandle counties of Texas the section of anhydrites exposed above the base of the Custer are also called Greer by Gould. Hence there are in reality three areas of the Greer. The extreme eastern and western areas are Custer and the area in the southwestern part of Oklahoma is Blaine or Cave Creek.

[9] T. W. Stanton, personal communication.

[10] C. N. Gould, "A New Classification of the Permian Red Beds of Southwestern Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 8, No. 3 (March, 1924), pp. 325–40.

Above the Greer Gould found a series of beds which he named the Quartermaster formation. Since the type locality is in the area of the western Greer, it is now known from field work and from the description given by Gould that the Quartermaster is synonymous with the Kiger division as first described by Cragin. It includes everything from the base of the Dog Creek shales up to the top of the highest red-beds. Unfortunately the name is still in current usage.

Another difficulty with the more restricted use of the name Quartermaster is that its base, as it is usually defined at present, is at the top of the Cloud Chief. Now, if the top of the Cloud Chief is marked by the Day Creek, or Alibates dolomite as it is now used by some, then the Quartermaster occupies the position of the Taloga. Cragin, in 1897, gave the name Taloga to all of the red-beds above the Day Creek dolomite.

Curiously, the name Taloga formation has been completely dropped from the literature, although, as far as the writer is aware, it is not pre-occupied and its status is as valid as that of the Whitehorse. Neither formation is valid in Texas and most of Oklahoma, as it is impossible to separate them on any logical basis. Any separation that may be made will be valid only if delimited by unconformities.

No further attempt is made in this paper to bring the problem of Whitehorse nomenclature up to date as the writer's chief purpose is to review the groundwork, which, due to the scarcity of publications, seems to have been forgotten by many in the field.

The writer's previous work gives many references[11] which may be consulted by those who wish to see how the previously described formations have subsequently been treated.

ANHYDRITES OF THE CUSTER

A study of the anhydrites of the Custer shows a marked absence of any large amount of gypsum. This is strongly emphasized by the location of the gypsum manufacturing plants. All of the plants using gypsum are located on the "Blaine of Texas." Core-drill work is used in order to determine that part of the section which contains the least amount of anhydrite and the highest amount of gypsum. This core-drill work is for development purposes and was used extensively at Acme in Hardeman County, Texas, where the gypsum is mined. The plants farther south use a stripping method. At Longworth, Fisher County, the Custer rests directly on a massive bed of gypsum. The basal part of the Custer at this locality contains several beds of anhydrite and great care is used in removing all of the Custer by

[11] R. Roth, *op. cit.*

FIG. 1.—Showing hydration of anhydrite. Center of east side of Sec. 240, S. W. Berry Survey, northeast of Sweetwater, Nolan County, Texas.

FIG. 2.—Showing hydration of anhydrite, east face of Double Mountain. Center of north side of Sec. 374, Blk. 2, H. & T. C. R.R. Co. Survey, Stonewall County, Texas.

stripping before taking the gypsum. The same condition exists at the large plant just east of Sweetwater, Nolan County, Texas. One plant, well above the base of the Custer, is located just south of Rotan, Fisher County. The material used is gypsite of Tertiary age, and is a bed of volcanic ash impregnated with gypsum. This gypsite contains plentiful remains of fresh-water fossils.

The almost complete alteration of anhydrite into gypsum, satin-spar, and selenite is characteristic of the "Blaine of Texas." A very interesting statement of the alteration which has taken place in the Blaine of Oklahoma is presented by Muir.[12] In this paper Muir is of the opinion that when anhydrite hydrates to gypsum the hydration is volume for volume and not molecule for molecule. The latter is the general belief of those who have worked on the problem in the past. There are several conditions in the field which strongly suggest that there is a decided volume change when hydration takes place. Figures 1 and 2 show beds of anhydrite which are covered by an incrustation of 1–4 inches in thickness. This incrustation is very porous and fibrous, tending to round all exposed edges. Slivers of anhydrite grade into this fibrous mass which is partially hydrated anhydrite.

As the anhydrite beds take up water it is plainly evident that a certain amount of swelling takes place. The formation of the incrustations shown in Figures 1 and 2 operates upon the anhydrite much the same as frost does upon rocks which are disintegrated through exfoliation. In Figure 2 it will be noticed that where water at times falls over the ledge of anhydrite, the incrustation is removed. This condition has been observed in many places, and it is apparent that the incrustation forms only where water has a chance to remain in contact with the anhydrite and is not immediately lost as run-off. After once formed, the incrustation, due to its porous nature, holds water and promotes growth.

The reader is referred to the discussion by H. L. Griley of Muir's paper.[13] All of the points brought out by Griley concerning the expansion are plainly evident in the surface expression of the Custer anhydrites. One may add that the excess of gypsum formed by the hydration of anhydrite may be found in the enormous amounts of selenite and satin-spar which occur in the beds adjacent to the primary beds of anhydrite. This is in addition to that which has been removed by solution and not deposited.

Lithologically the anhydrites of the Custer are quite different from

[12] J. L. Muir, "Anhydrite-Gypsum Problem of Blaine Formation, Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 18, No. 10 (October, 1934), pp. 1297–1312.

[13] J. L. Muir, *op. cit.*, pp. 1310–11.

FIG. 3.—Contact of Custer and Blaine of Texas. Center of north side of Sec. 232, W. L. Coulson Survey, north of Eskota, Fisher County, Texas.

FIG. 4.—Lithologic character of Custer anhydrite. Palo Duro Canyon, Blk. 6, I. & G. N. R.R. Survey, Randall County, Texas.

those which still remain in the underlying Blaine. In general they are very thinly laminated. This lamination is produced by pink bands separated by white, although other colors, such as gray and gray-green are common. The Germans name such anhydrite "tripe stone." To a large extent the anhydrites of the Blaine lack this lamination. Anhydrites of the Custer in many places contain a great many large frosted sand grains. These grains, in many places, are colored orange-red, and do not occur in the Blaine. Figure 4 shows a typical exposure of a Custer anhydrite. Another feature of the anhydrites of the Custer is that where erosion is not active the presence of anhydrite is not evident on the surface. This is due to the fact that most of the inclosing beds are porous sandstone which allows meteoric waters to carry off the dissolved or hydrated anhydrite, thus leaving a mantle of sandstone. The inclosing beds of the Blaine gypsum are shales which are not nearly so pervious as the overlying beds; hence the massive beds of gypsum stand out in relief. In the Custer as exposed in Texas, anhydrites are not confined to any part of the stratigraphic sequence; in other words, from the base to the top, one may expect massive beds of anhydrite. In lateral extent it is noted that certain areas contain much more anhydrite than others.

In tracing the Custer westward beneath the surface, it is found that the equivalent of at least all of the exposed parts, and perhaps some of the younger parts of the Custer which are not exposed, change over to anhydrite and dolomite. In the main part of the Permian basin the upper Custer contains salt and polyhalite with some anhydrite and terra-cotta shales, and much orange polished sandstone.

EFFECT OF KARST LANDSCAPE

The present character of the Custer has been influenced greatly by the terrane upon which it was deposited. This is true of every formation in that its present expression is the result of what has preceded. The Cave Creek, or what has later been called the Blaine, was originally so named because of the great number of caves. These caves are the result of solution and occur from Kansas to Texas. Sink holes and slumpage are synonymous with the Cave Creek. Subterranean drainage is well established in much of the area. Upon this karst landscape the Custer was deposited. The sandy nature of the Custer allows free circulation of meteoric waters with the result that the forces which were producing a karst landscape in the Blaine have not been completely arrested, but are continuing. Where the contact between the Custer and the Blaine is exposed, local dips in the Blaine continue up into the Custer, but the degree of dip is less. All of the sediments

above the zone of connate water have continued to slump; therefore, erratic dips are common to this part of the red-bed section. Salt in the Blaine and in the Custer has also added its effect by solution. In the area covered by this article, the greatest amount of slumping occurs in the Panhandle of Texas.

A good discussion of karst landscapes is given by Dicken.[14]

EPICYCLES OF EROSION

No area in the Mid-Continent offers better facilities for studying the effect of rapid surface run-off, and the accompanying acceleration of erosion, than that of the Custer formation. During the spring and early summer periods frequent thunderstorms traverse the area from west to east. These storms are usually very local in nature and precipitate an inch or more of water during a period of a few minutes. Along with the rain it is not at all unusual to have heavy falls of hail. Half-inch, and larger stones are not uncommon and so choke local drainage systems that a wall of water, hail stones, and mud rushes into the larger streams. During the season of these rains, the amount of sediments transported is tremendous. Whether this type of precipitation is something new or not is difficult to determine, but from all of the early historical accounts, it is known that thunderstorms have always been the common experience of the traveller on the Great Plains. In any event, the physiographic features of the area are rapidly being changed and two epicycles of erosion are in rapid progress at the present time.

The old topography of the area shows a rolling plain with smooth and gentle slopes. Figures 5, 6, and 7 show that originally there existed a smooth terrane with few steep declivities. Figures 5 and 6 show that even the erosional remnants of the Dozier Mounds dolomite were smoothed over. Then gullies commenced and attained considerable headway. These first gullies may be noticed in Figures 5, 6, and 7. It is surprising that this first epicycle of erosion ceased to degrade and started a period of aggradation. This is difficult to explain. The present epicycle of erosion has started degradation again with the formation of sharp gullies within the floors of the older gullies. Figure 7 shows the results of this latest epicycle.

The second or present epicycle may be explained by a change in the grass coverage of the High Plains area. For years this area has been used for grazing, resulting in the almost complete exposure of the ground to the action of meteoric waters.

[14] S. N. Dicken, *Jour. Geol.*, Vol. 43, No. 7 (1935), pp. 708–729.

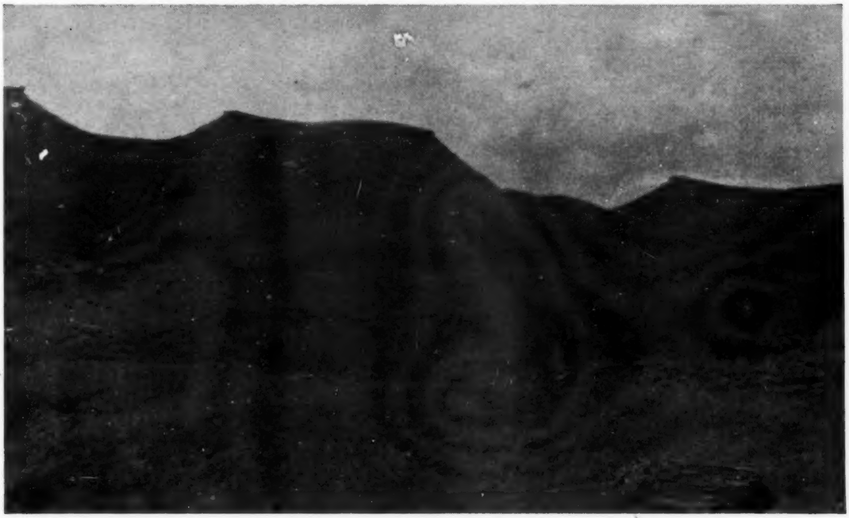


FIG. 5.—Type locality of the Dozier Mounds dolomite. Locally known as Rocking Chair Mountains. Shows result of epicycle of erosion and slumping. N.E. ¼ of Sec. 28, Blk. 16, H. & G. N. R.R. Survey, Collingsworth County, Texas.

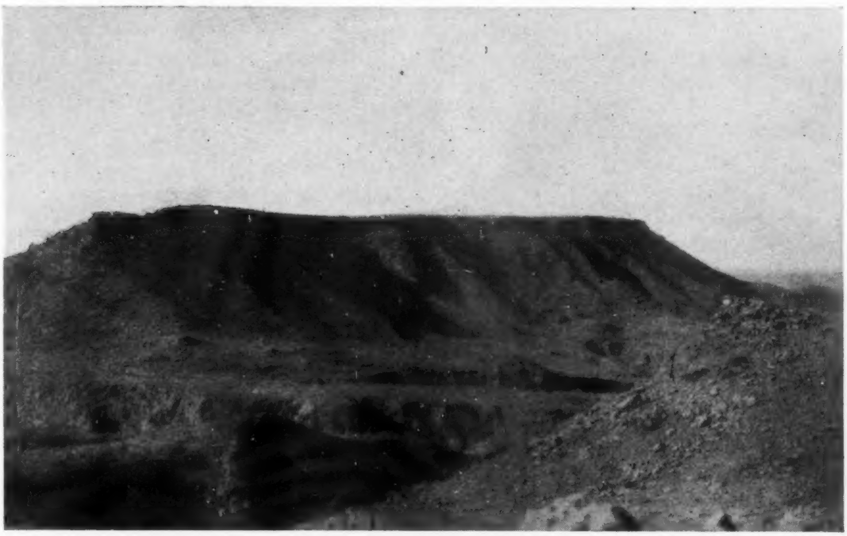
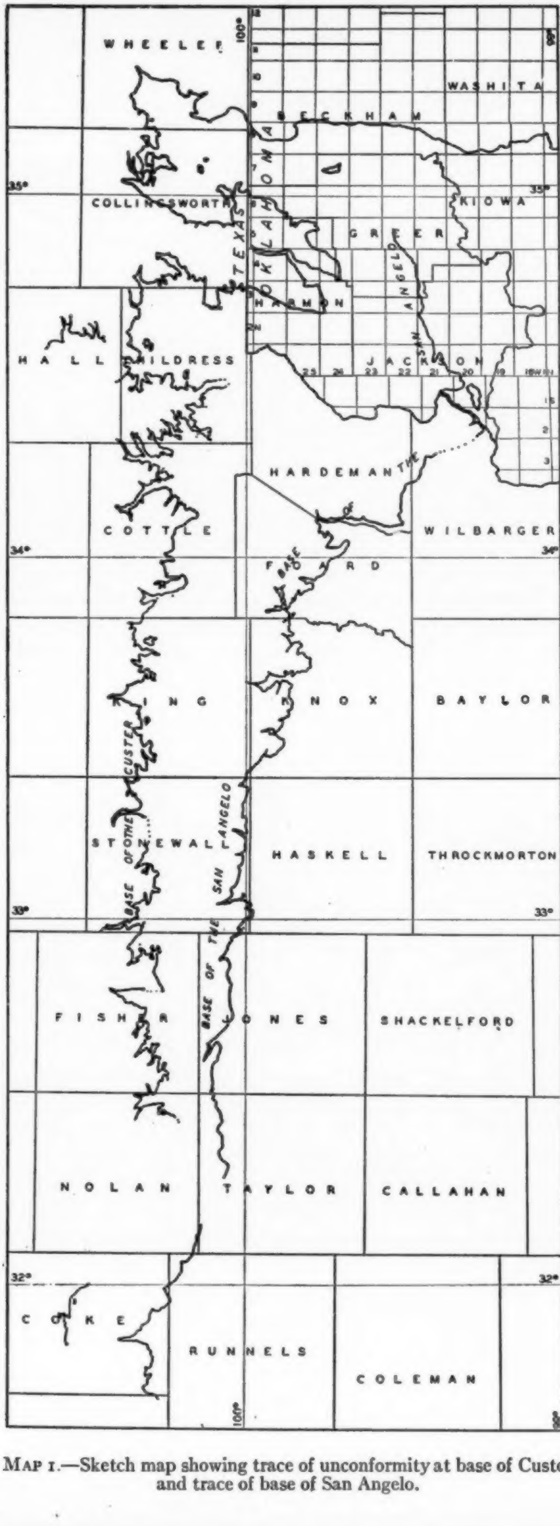


FIG. 6.—Hogback Butte, noted landmark capped by Dozier Mounds dolomite. Shows result of epicycle of erosion. Center of Sec. 19, Blk. 1, T. A. Thompson Survey, Hall County, Texas.

FIG. 7.—Results of epicycles of erosion. Sec. 6, Blk. A, A. B. & M. Survey, Hall County, Texas.

FIG. 8.—Angular unconformity at base of Custer. Sec. 4, Blk. H, A. B. & M. and also B. S. and F. Survey, Childress County, Texas.



MAP I.—Sketch map showing trace of unconformity at base of Custer and trace of base of San Angelo.

UNCONFORMITY AT BASE OF CUSTER

The recognition of the unconformity at the base of the Custer formation depends on the geographical attitude of the observer. If the contact is observed in a local area it will be found that there is no angular unconformity; the break is lithologic. This condition has led to the many confusing reports about the presence of an unconformity at the base of the Custer.

It must be pointed out that if two series of strata are separated by an unconformity, that unconformity will be hard to recognize if the two series of strata are parallel in bedding. This condition exists in the Mid-Continent block which for long geological periods was quiescent. During the time interval separating the Blaine from the Custer the region was subjected to epeirogeny but no local orogeny has as yet been recognized. Hence from the local viewpoint, an unconformity is hard to demonstrate. The strongest evidence is the profound change in environment as expressed in the change of sediments.

If one takes the other point of view and looks at the problem from a regional angle, including the area of several counties together, the unconformity is obvious. Thus, locally in Wheeler and Collingsworth counties, there are approximately 300 feet of strata between the base of the Custer and the base of the San Angelo. In Childress and Cottle counties there are about 800 feet of strata in the same interval. This interval progressively thins southward and becomes markedly thinner in Nolan and Coke counties. In Coke County, especially, it is observed that the "Blaine of Texas" or the Cave Creek has been removed and the Custer rests on the upper sandy facies of the San Angelo. This regional aspect also occurs in Oklahoma. Map 1 shows the trace of the base of the Custer and the base of the San Angelo, and brings out the pronounced divergence of strike between the two horizons. The San Angelo conforms to the trace of the other beds below the Custer.

The local aspect of the unconformity may be plainly seen in a few places. Figure 8 presents a local condition of some steeply dipping beds of the "Blaine of Texas." This condition is extremely rare. Here, as in most other places, there is no conglomerate at the base of the Custer. Figure 9 shows the pronounced change in the character of beds on both sides of the contact. Locally there is fine conglomerate at the base of the Custer in Fisher, Nolan, and Coke counties. It is composed of well rounded, large quartz grains, and in some places there are some small pebbles of siliceous metamorphic rocks of various colors. These pebbles seem to be more stable than chert as there is no alteration to tripoli. Figures 11 and 12 show the character of the base of the Custer. The fine conglomerates are very plentiful at these

FIG. 9.—Base of Custer. Sec. 793, Blk. H, W. & N. W. Survey, Hall County, Texas.

FIG. 10.—Erosional character of upper Custer. SE. cor. of Sec. 21, 4 miles north and 1 mile east of Quitaque, Briscoe County, Texas.

FIG. 11.—Same locality as shown in Figure 3, Nolan County, Texas.

FIG. 12.—Custer resting on massive gypsum. One mile west of locality of Figure 1, Nolan County, Texas.

localities; the average diameter of these pebbles is scarcely more than one millimeter. This size by comparison with other sands of the Custer is very large.

Two economic features resulting from the unconformity at the base of the Custer are: (1) subaëreal erosion has developed the commercial deposits of gypsum underlying the Custer; and (2) subaëreal erosion has developed porosity in the limestones which now underlie the Custer in the Permian basin of West Texas. This porosity serves as an available reservoir for the accumulation of oil. Much of the petroleum produced from limestone comes from this horizon, though the limestone is not all of the same age.

PALEOGEOGRAPHIC CONDITIONS OF DEPOSITION

There are very few facts which help in speculating on the conditions under which the Custer was deposited. It is well established that in the main Permian basin of West Texas a very large body of water was shut off from the open sea, and was completely desiccated after short periods of reincursion. Non-fossiliferous dolomites were first laid down upon an irregular surface. These dolomites were succeeded by thin beds of dolomite alternating with anhydrite. Next in ascending the section, the anhydrites predominate with thin beds of eolian sands separating the beds of anhydrite. Lastly, there are thick beds of salt with anhydrite in minor amounts along with eolian sands, polyhalite, and terra-cotta shale. This is the section below the Rustler dolomite and is found especially in deep borings. As one leaves the Permian basin it is noticed that this section of evaporites and chemical precipitates gradually gives way to eolian sands and terra-cotta shales. This transition happens on all sides except farther southwest where the Castile anhydrite crops out. Apparently the intermittent passageway to the open sea was toward the southwest. The deposition of sediments has resulted similar in nature to those at Stassfurt, Germany. It is unfortunate that studies of the main Permian basin section must be confined to samples taken from well borings.

Concerning the eolian nature and implied environment of the Custer sandstones there is very little evidence except by microscopic analysis of the polished sand grains. One physical feature is preserved near Mountain View, Oklahoma, and elsewhere in central Oklahoma, but so far it has not been found in Texas. This is fossil sand dunes. Figure 13 shows these fossil sand dunes and Figure 14, shown for comparison, was taken in the Zion Canyon, Utah, where the formation is known as the White Cliff sandstone. In both places these parabolic lines of bedding may be followed for 100 feet or more.

FIG. 13.—Fossil sand dunes in basal Custer. SW. cor. of Sec. 19, T. 7 N., R. 13 W., Oklahoma.

FIG. 14.—For comparison with Figure 13. Fossil sand dunes in Jurassic sandstone of Zion Canyon, Utah.

The principal difficulty in regional correlation and even local tracing of beds is due to the continental type of the sediments. The history seems to be that of a great plains area swept with sandstorms and sand dunes. The southern part of this area contained a desiccating sea which was subject to wide fluctuations in its boundaries, but as time progressed it continually shrank in size until complete desiccation prevailed before Rustler time. The Rustler represents a brief recurrence of the sea which deposited a widespread bed of dolomite and then retreated rapidly.

The unconformity at the base of the Santa Rosa marks the close of one of the most interesting phases of deposition in the upper red-beds of the Mid-Continent region.

WHEELER COUNTY, TEXAS

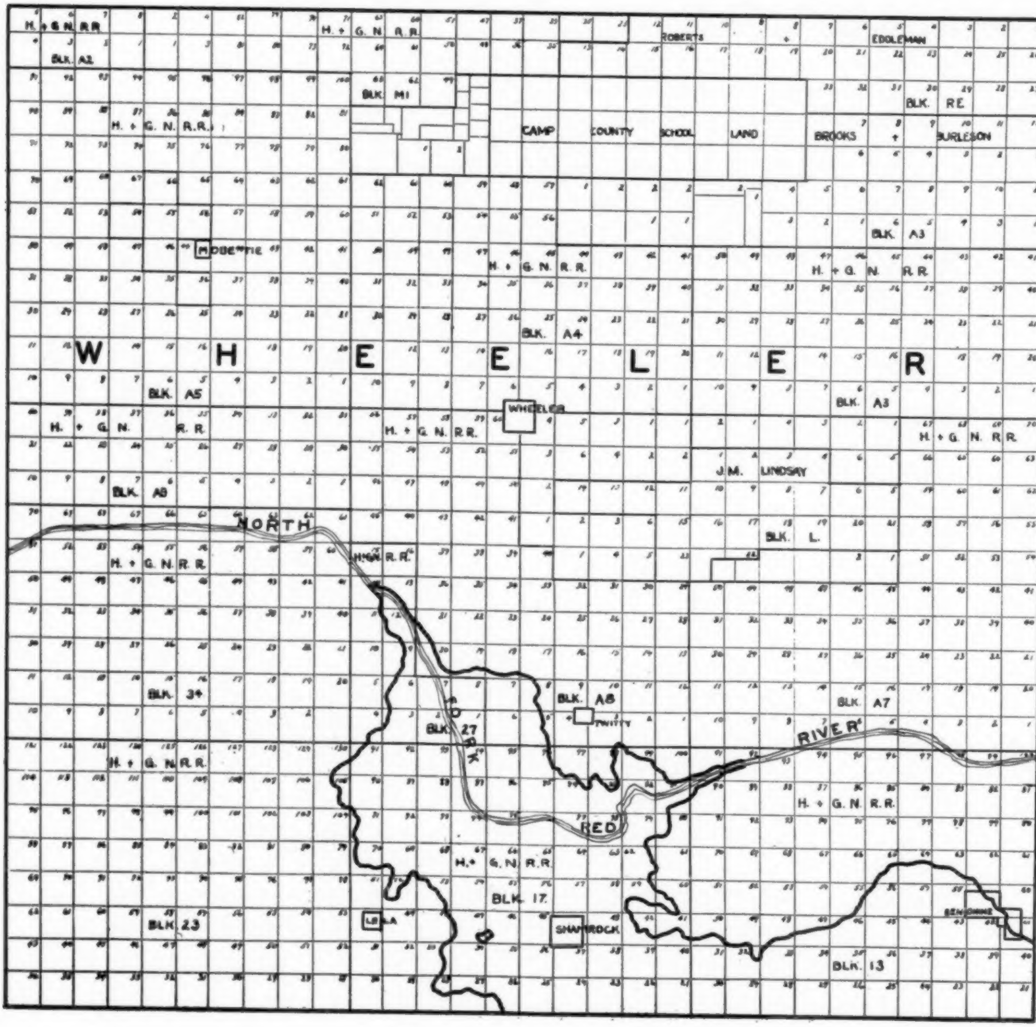
This is the first county in the Panhandle of Texas where the base of the Custer may be discerned as it enters Texas from Oklahoma. From Shamrock east to the state line the contact is very poorly exposed due to sand dunes. North and west of Shamrock the Custer is well exposed, although there is much slumping. Some anhydrites occur along the road to Twitty north of Shamrock, and some fair exposures of the Dozier Mounds dolomite are also found there. The low hills west of Shamrock are formed by the Dozier Mounds dolomite. Good exposures may be seen both east and west along the North Fork of the Red River. Due to the overlapping Tertiary and Quaternary sands and caliche which here almost reach the "Blaine of Texas," there is little of the total section of Custer exposed.

Gould[15] calls all of the red-beds in Wheeler County, above the Greer, the Quartermaster, thus drawing the line at the top of the massive gypsum. Since the Custer in parts of the area rests directly on the massive gypsums and in other parts on some of the reddish brown or chocolate shales associated with what is now known to be the "Blaine of Texas," it thus becomes necessary to use a different classification.

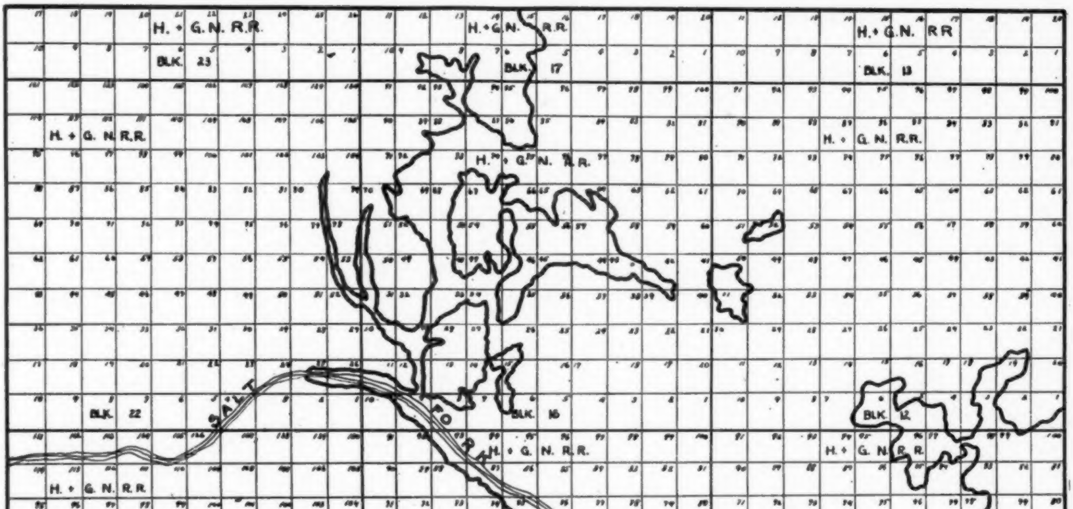
COLLINGSWORTH COUNTY, TEXAS

In some respects the trace of the base of the Custer in Collingsworth County is of considerable interest. The structurally high area northeast of Wellington and north of the Salt Fork of Red River contains many thin outliers of Custer. On the northeast side of the county where the Custer enters Oklahoma it rapidly thickens due to structural conditions. In the southeast corner of the county, at Dodson-

[15] C. N. Gould, *U. S. Geol. Survey Water Supply and Irrigation Paper 154* (1906), pp. 54–55.



MAP 2.—Wheeler County, Texas.



MAP 3.—Collingsworth County, Texas.

ville, the Custer again swings back into Texas from Oklahoma for the last time.

Along the west side of the county, the Dozier Mounds dolomite is splendidly developed. Here it forms excellent outliers which are in some places 8 or more miles east of the main outcrop. The strike of the Dozier Mounds dolomite is somewhat east of north. The greatest relief caused by this dolomite is in the southwest part of the county. The Dozier Mounds dolomite is locally very calcareous.

Gould[16] again divides the red-beds of this county into the Greer and Quartermaster.

Since this county contains some of the best exposures of the Dozier Mounds dolomite as well as being the type locality, it is best to give the original description of Gould:[17]

> Near the middle of the Quartermaster formation, as exposed in Collingsworth and Hall Counties, there is a ledge of rather hard, red or pinkish, more or less oölitic sandstone, which on weathering gives rise to a number of flat-topped buttes and ridges.

Figure 5 shows the type locality of the Dozier Mounds dolomite, NE., NE., NE., of Sec. 28, Blk. 16, H. & G. N. Survey, Collingsworth County.

Custer (Dozier Mounds dolomite member)

Feet	
8	Cross-bedded oölitic pink dolomite
100	Orange polished sandstone and silt
	Section incomplete

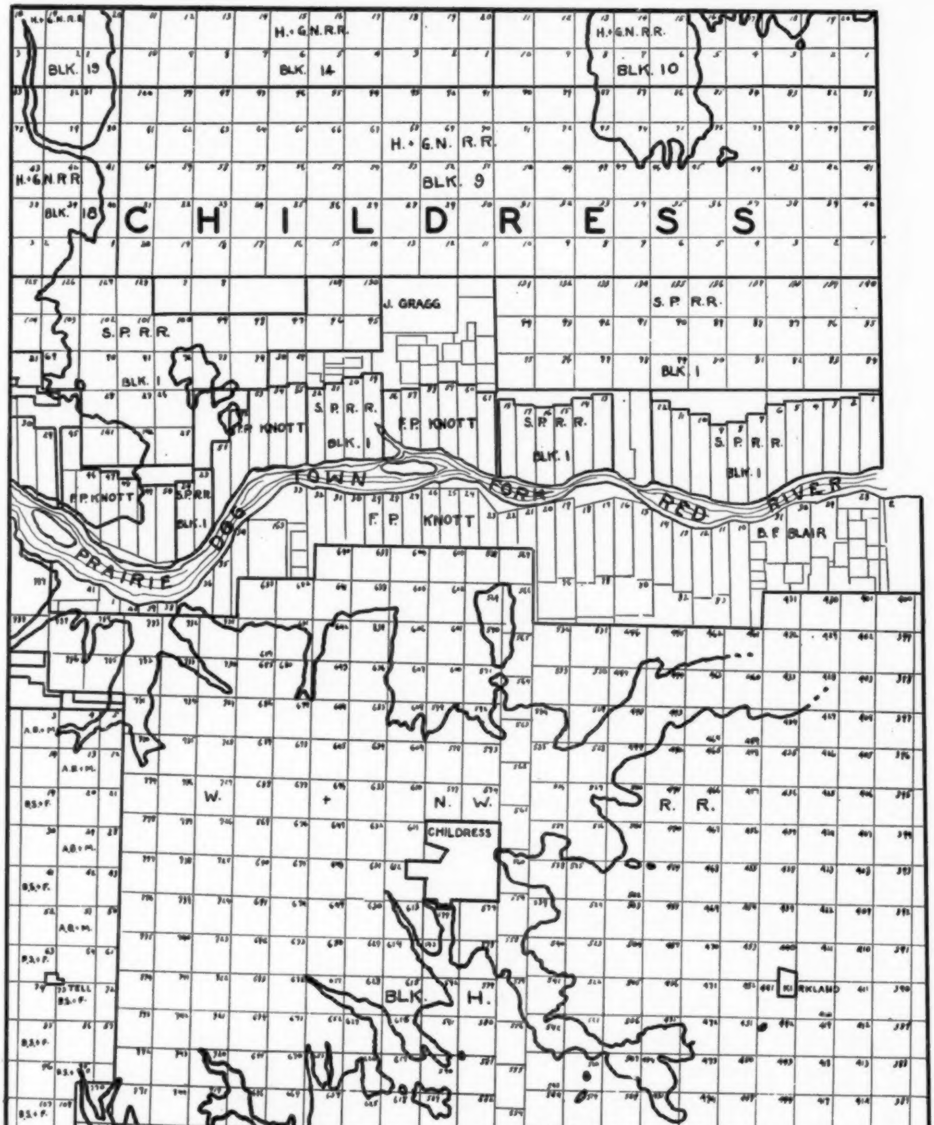
The character of the interval between the base of the Custer and the Dozier Mounds dolomite may best be shown by the following section measured just east of the Dozier Mounds Post Office, cen. of Sec. 28, Blk. 16, H. & G. N. Survey, Collingsworth County. The section extends northward up the draw to the windmill and thence due east to the top of the highest hill. The base of the Custer may be as much as 10 feet in error because of the tremendous amount of slumping.

Custer (Dozier Mounds dolomite member)

Feet	*Inches*	
10	4	Oölitic, pink, cross-bedded dolomite; very fossiliferous and in places almost a coquina
36	2	Orange polished sandstone
82	8	Orange polished sandstone and terra-cotta shale
20	8	Orange polished sandstone; top of this interval at base of windmill; part of sandstone shows leached spots and there is no Childress dolomite; much of interval to base of Dozier Mounds is covered

[16] C. N. Gould, *op. cit.*, p. 59.

[17] *Ibid.*, p. 22.



Map 4.—Childress County, Texas.

"Blaine of Texas"

15	6	Chocolate-brown and green shale, and some gray, silty, dolomite shells; base of Custer very irregular

In the southwestern part of the county the Dozier Mounds dolomite is much better developed than at the type locality. It should also be noted that the interval between it and the base of the Custer has increased.

The following section starts in the center of the west side of Sec. 43, Blk. 19, H. & G. N. Survey, Collingsworth County, and continues to the top of the hill.

Custer (Dozier Mounds dolomite member)

Feet	*Inches*	
19	6	Cross-bedded gray and pink dolomite; upper 5 feet softer and locally rubbly; oölitic zones occur throughout; basal contact sharp with no apparent unconformity
80	6	Orange polished sandstone
93		Orange polished sandstone; much of this covered and contains several beds of anhydrite; exact position not determined; no Childress dolomite present

"Blaine of Texas"

Chocolate shales and some gypsum and selenite; this section contains thickest section of Dozier Mounds dolomite so far observed; very fossiliferous, especially in the lower half; relief due to dolomite bed probably greatest in this area

CHILDRESS COUNTY, TEXAS

In this county the base of the Custer meanders more than in any other county where exposed in Texas. This is due to three main causes: (1) the structural feature occupying the north half of the county; (2) a major stream crossing the county from west to east; and (3) the regional dip of the southern part of the county being almost flat. The dip is westward and is only a few feet to the mile. The base of the Custer is very easy to follow in this county as the Childress dolomite occurs 3–20 feet above it.

The type section of the Childress dolomite, SW. cor. of Sec. 526, W. & N. W. Survey, Childress County, is as follows.

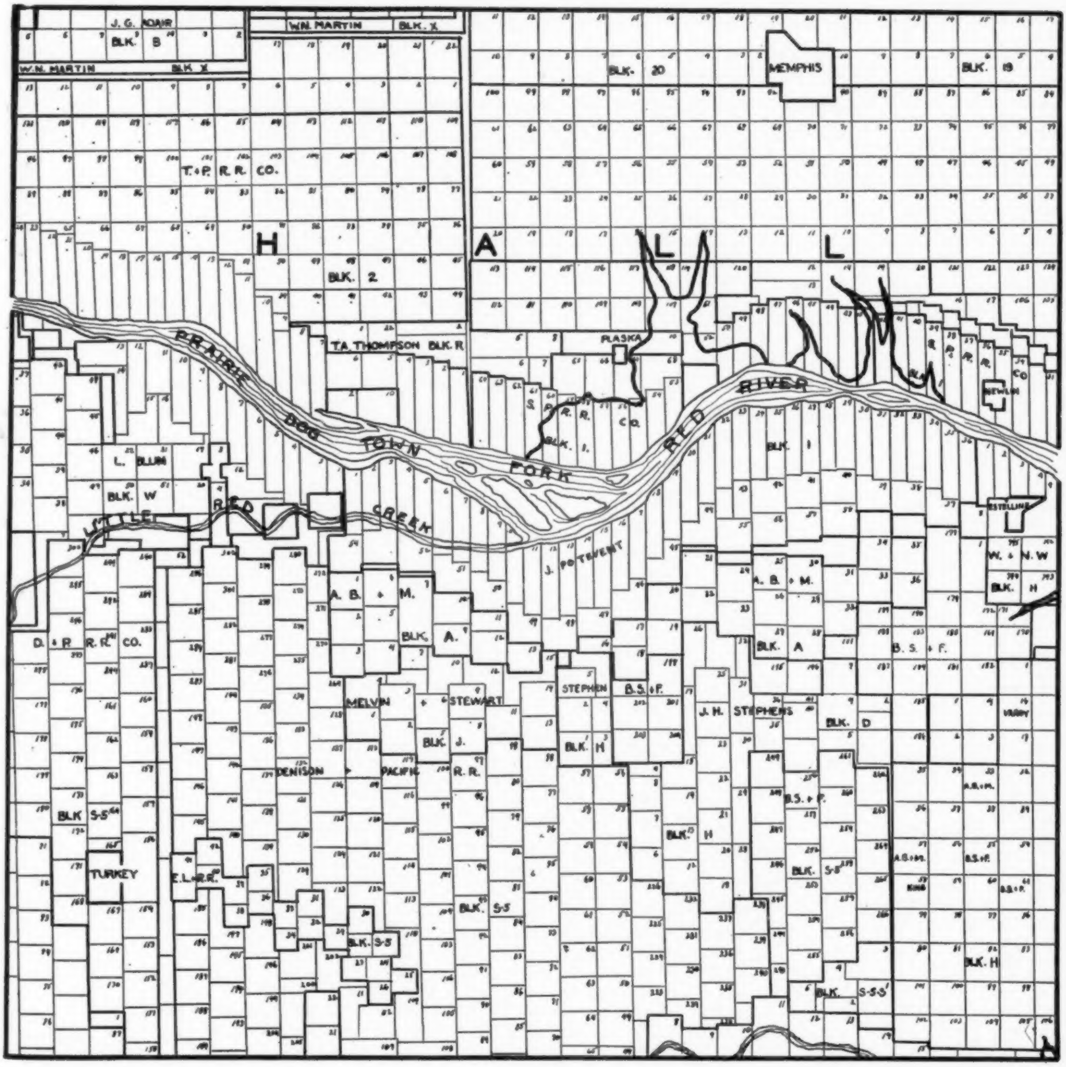
Custer (Childress dolomite member)

Feet	*Inches*	
2		Platy and laminated pink and gray dolomite; weathers grayish; tendency to weather into plates about 4 inches thick
20	8	Fine, orange polished sandstone

"Blaine of Texas"

Thin-bedded shale, chocolate and gray with some pinkish dolomite dikes

The Childress dolomite member is a good mappable unit in Childress and Cottle counties; it is also of value for regional correlations. Its thickness varies considerably and in many places it has turned



Map 5.—Hall County, Texas.

into anhydrite. However, everywhere at this particular stratigraphic horizon there seems to be either a dolomite or an anhydrite bed present. This was noticed as far south as Coke County.

The following section at the high hill just east of Gould, NE. cor. of Sec. 6, T. 2 N., R. 24 W., Harmon County, Oklahoma, shows how the Childress dolomite varies and becomes anhydrite.

Custer

Feet	*Inches*	
2		White anhydrite
2		Red-brown gypsiferous anhydrite, conglomeratic in places
	18	White anhydrite. 1–3 inches gray dolomite, very local
8		Orange polished sandstone

"Blaine of Texas"

Brown and light gray, blue-green shale; great abundance of gypsum and selenite veins

In the southwest part of Childress County the 100-foot interval above the Childress dolomite contains many thick beds of anhydrite. Some are several feet in thickness, but none continues for any distance. These anhydrites are plentiful near Tell. The west-central side of the county, just east of Estelline, is one of the few areas where an angular unconformity separates the Custer from the lower formations.

HALL COUNTY, TEXAS

The base of the Custer in this county is found only along the north side of the Prairie Dog Town Fork of the Red River. The most interesting geologic features of this county are the fine examples of outliers which the Dozier Mounds dolomite forms. The transition of sandstone on the north side of the river into sandstone and thick beds of anhydrite on the south side is characteristic of the Custer.

The following three sections of the lower part of the Custer are of interest because they show the general lithologic features.

The section of Hogback Butte, 8 miles south of Memphis, cen. of Sec. 19, Blk. 1, T. A. Thompson Survey, was measured from the stream west to the top of the butte.

Custer (Dozier Mounds dolomite)

Feet	*Inches*	
16	6	Cross-bedded pink and gray oölitic sandy dolomite; sun cracks on the upper surface; lower part of dolomite very fossiliferous; some shale and sand conglomerates at base
75		Orange polished sandstone; for most of this section of sandstone is coarser than that below; there are thin zones which are well bedded; this interval contains at its base a lenticular bed of anhydrite which is on south side of butte; this bed extends about 500 feet, and thins from 2 feet to nothing northward
85	2	As above, but no anhydrite
2	5	White, gray, and salmon pink, laminated anhydrite; this bed traced several miles
55		Fine, orange polished sandstone; some pink dense dolomite as veins; also some speckled gray dots in sandstone

Custer (Childress dolomite member)
8 Laminated dolomite, in most places gray
4 Orange polished sandstone

"Blaine of Texas"
Highly contorted beds of gypsum, selenite, and chocolate-brown shale

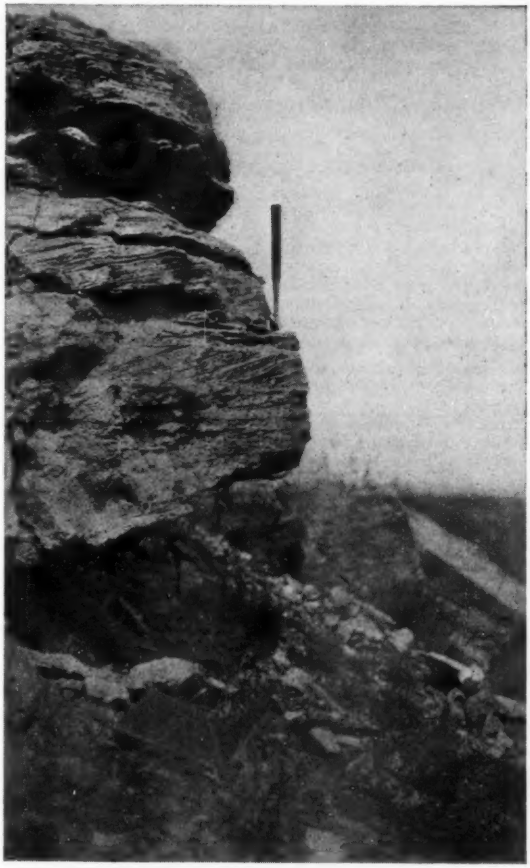


FIG. 15.—Detail of Dozier Mounds dolomite. Notice cross-bedding. Hammer handle is 12 inches in length. Mt. Nebo is located about 4 miles west of Estelline in J. W. Phillips Land, Blk. 15, Hall County, Texas.

The section of Mount Nebo, or Phillips Mountain, about 4 miles west of Estelline in J. W. Phillips Land, Blk. 15 (Fig. 15) is as follows.

Custer (Dozier Mounds dolomite)

Feet	*Inches*	
5		Platy, grading downward to massive, cross-bedded, salmon-pink, dolomitic sandstone
7		Massive, salmon-pink, dolomitic sandstone, softer in lower part, fossiliferous
6		Very dolomitic, salmon-pink, cross-bedded sandstone; fossiliferous at base
1		Fine sandy material with some thin dolomitic shells about 2 inches thick
15	6	Fine, orange polished sandstone, micaceous in places
36	2	Fine, orange polished sandstone, base not exposed

The following section is from Phillips Petroleum Company's, Hughes No. 1, cen. of N.½ of Sec. 4, Blk. H, J. H. Stephens Survey.

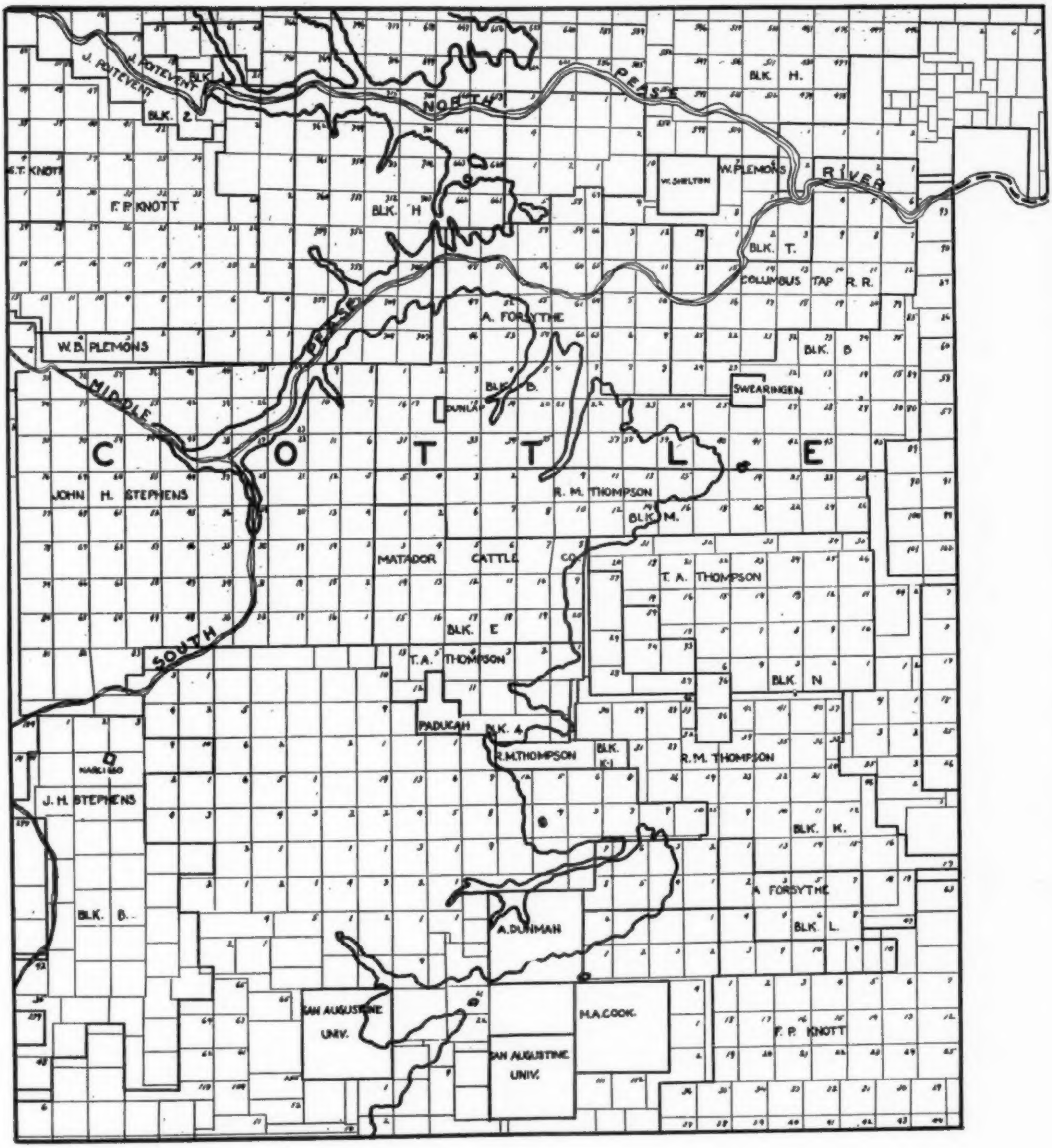
Custer

Depth in Feet	
40	No samples
50	Fine, orange polished sandstone
60	As above, trace of selenite
70	Fine, orange polished sandstone and selenite
80	Fine, orange polished sandstone and trace of selenite
90	As above and trace of anhydrite
100	Fine, orange polished sandstone and selenite
	Dozier Mounds dolomite member
110	Fine, orange polished sandstone with large frosted sand grains and pink dolomite
120	Terra-cotta grits, oölitic pink dolomite and anhydrite
130	As above and gypsum
160	Fine, orange polished sandstone and selenite
170	Fine, orange polished sandstone, some leached
180	Terra-cotta grits, selenite and some large frosted sand grains
190	Selenite and anhydrite with terra-cotta grits
200	Fine, orange polished sandstone and selenite
210	Fine, orange polished sandstone and anhydrite
220	Fine, orange polished sandstone and selenite
230	As above with some large frosted sand grains
240	Fine, orange polished sandstone and selenite
250	Fine, orange polished sandstone and selenite with some large frosted sand grains
260	Selenite, terra-cotta grits and large frosted sand grains
270	Orange polished sandstone and selenite with large frosted sand grains
290	Orange polished sandstone and selenite
300	As above and large frosted sand grains
330	Orange polished sandstone and some selenite
360	Fine, orange polished sandstone and some selenite
370	Terra-cotta grits, anhydrite and large frosted sand grains
380	Terra-cotta grits, selenite and large frosted sand grains
390	Terra-cotta grits, selenite
410	Fine, orange polished sandstone and selenite
430	Fine, orange polished sandstone and some selenite
440	Coarse, orange polished sandstone and some selenite

"Blaine of Texas"

Earthy selenite, brownish color
No Childress dolomite could be identified in the well cuttings

Attention is called to the marked increase in the interval between the Dozier Mounds dolomite and the base of the Custer which occurs as one traces the section southwestward from Collingsworth County.



MAP 6.—Cottle County, Texas.

Several beds of anhydrite and its hydrated form are also present. These beds occur in what has loosely been called the "Whitehorse of Texas."

COTTLE COUNTY, TEXAS

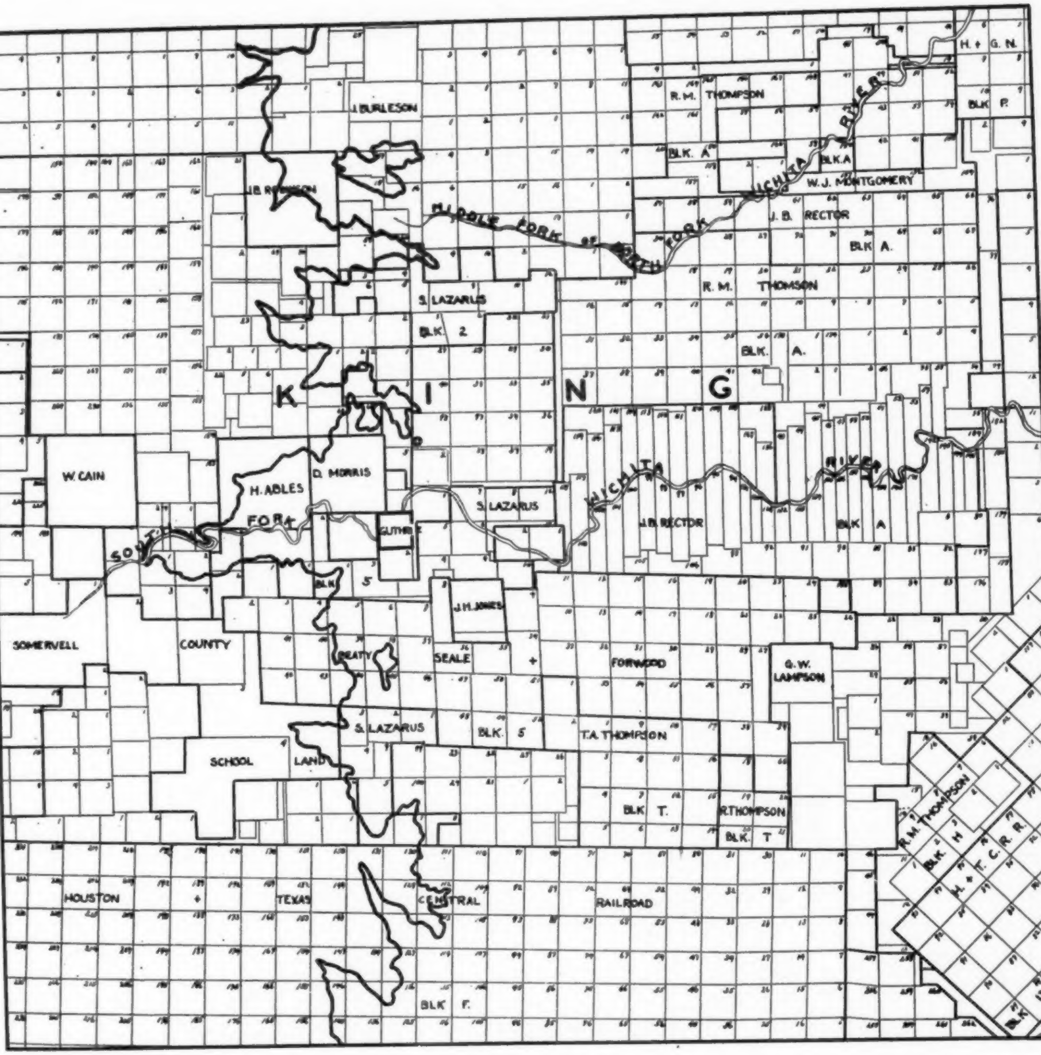
The trace of the base of the Custer in Cottle County is still highly irregular in outline. The Childress dolomite member extends across the county, though it is thin. The topography of Cottle and Motley counties is of considerable interest because of the wide belt of Custer exposures. Going westward one first crosses the belt of highly dissected beds of the "Blaine of Texas." The vegetation consists of cedars and pinons which stop abruptly at the line of the Childress dolomite member. Next the broad and gentle rolling uplands are largely covered with mesquites and grassy areas. Most of this belt is cultivated. This type of topography is again interrupted along the western line of Motley County where massive beds of anhydrite occur. This area is intricately dissected and cedars and pinons recur. Above this there is a narrow area of uplands near the foot of the High Plains where the last rapid rise occurs. These uplands are covered with mesquites and grass. The High Plains are grass-covered where not cultivated.

An important facies of the lithologic character of the Custer in Cottle County is the extreme abundance of anhydrite beds. These continue to the base or just above what is left of the Childress dolomite member.

The following is a section of the base of the Custer, center of the west side of Sec. 49, A. Forsythe Survey, Blk. B, east side of U. S. Highway 83.

Custer	
Feet	
	Orange polished sandstone, not measured
3	Childress dolomite member and anhydrite
10	Orange polished sandstone, leached at base
"Blaine of Texas"	
	Chocolate-brown shale

In the extreme southern part of the county and just north of the A. Dunman Survey, the Childress dolomite is represented by a dark gray porous dolomite about one foot thick. Just north of the San Augustine University Blk., south side of Sec. 2, A. B. Long Survey, Abstract 1507, the Childress dolomite member is represented by a foot of oölitic pink-to-gray dolomite. Some beds near Narcisso have been mapped incorrectly as Childress dolomite, but they are above the true Childress dolomite.



MAP 7.—King County, Texas.

The following section is measured just west of Narcisso, Motley County, center of the west side of Sec. 13, A. B. & M. Survey.

Custer

Feet	*Inches*	
25	10	Orange polished sandstone
4		Orange polished sandstone; anhydrite grades laterally to dolomite; this bed has been called Childress dolomite
51	8	Orange polished sandstone
5	2	Massive white and pink crinkly anhydrite; some thin gray laminated beds of dolomite near base, 3–4 inches thick; this bed also changes laterally to dolomite 1–2 feet thick
		Base not exposed

KING COUNTY, TEXAS

Generally the trace of the base of the Custer in King County is a straight line. This is due to two main reasons: (1) there is no large west-to-east drainage; and (2) the regional dip westward is increasing. The gradual bevelling of the "Blaine of Texas" southward becomes apparent in this county. The chocolate-brown shale which generally separates the Custer from the dolomites and gypsum of the "Blaine of Texas" thins out in this county.

The Childress dolomite member is replaced almost completely by anhydrites. The following typical section of the base of the Custer, cen. of Sec. 68, Louis de Fous Survey, about 3 miles north of Guthrie, shows the character of the contact.

Custer

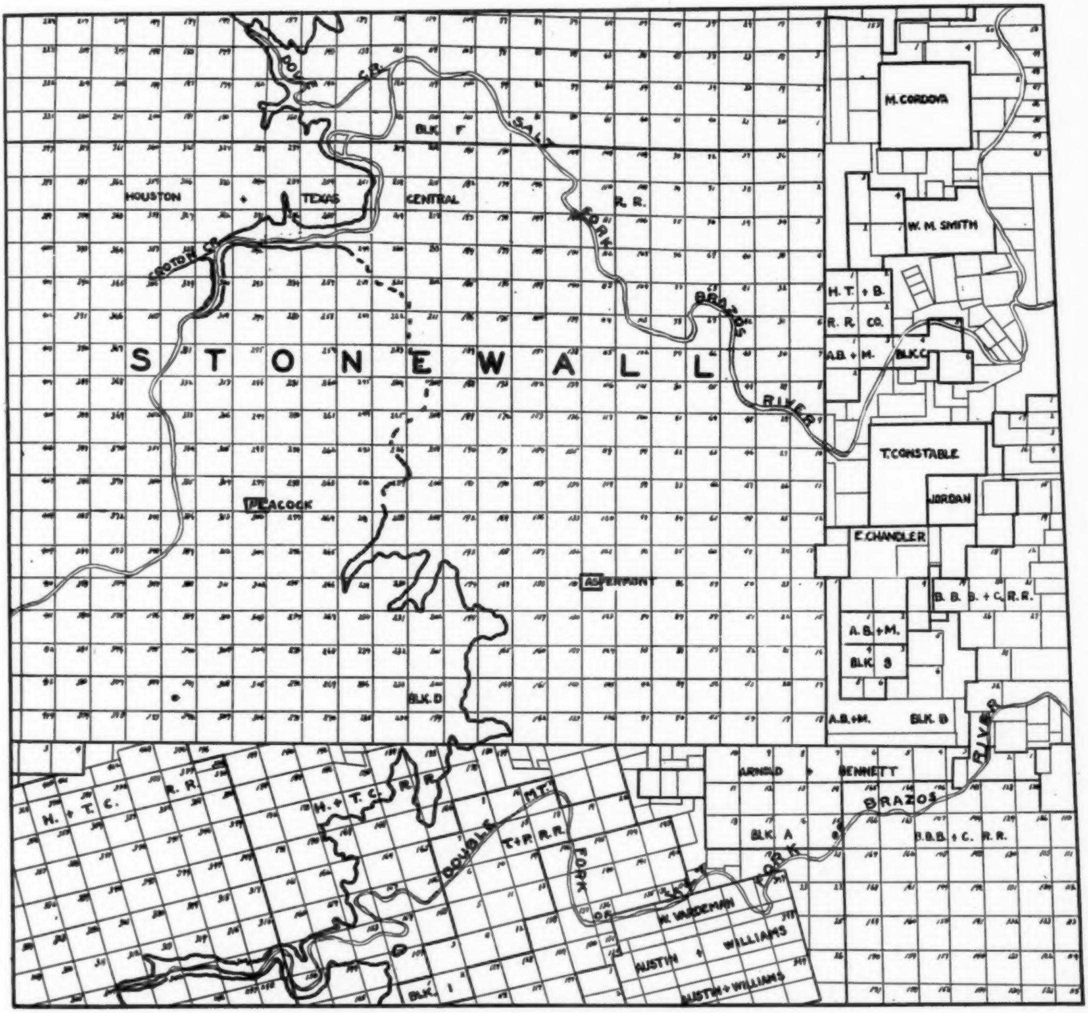
Feet	
2	Gray and pinkish anhydrite with some thin gray dolomite shells; much incrustation of hydrated products of anhydrite; this is Childress dolomite horizon
10	Fine, orange polished sandstone; leached at base

"Blaine of Texas"

34	Chocolate-brown shale, selenite, and thin beds of gray dolomite and gypsum
4	Gypsum and a little anhydrite; some thin shells of gray dolomite and some brown shale in lower part; State geological map of King County shows this 4-foot bed as Childress dolomite; below is unmeasured interval of chocolate-brown shale and selenite with some gypsum

In mapping this county it should be mentioned that great difficulty was encountered in finding adequate roads. Most of the county is ranch land. The escarpment just below the base of the Custer prohibits automobile travel. As survey lines are not marked it is very difficult to establish accurate locations.

Several rather massive beds of anhydrite and some thin dolomites are present in the basal part of the Custer.



Map 8.—Stonewall County, Texas.

STONEWALL COUNTY, TEXAS

This county is of considerable geological interest. It is crossed by two major streams flowing east, one in the north and one in the south, causing two indentures in the trace of the base of the Custer. Overlap of the "Blaine of Texas" is pronounced. Just west of Aspermont there is a very prominent escarpment formed by the "Wagon Yard" gypsum member of the "Blaine of Texas." From south to north the base of the Custer varies from 0 to 30 feet above this bed. In the northern part of the county the "Wagon Yard" gypsum forms a prominent escarpment extending into King County. In this area the interval between the base of the Custer and the top of the "Wagon Yard" gypsum is highly irregular. It is about 40 feet below the Ward anhydrite.

An area between Swenson and the Salt Fork of the Brazos River is covered by "blow sand" of Quaternary age which has covered all of the older sediments. This is the first covered area encountered south of Wheeler County and it led to difficulty in correlating members of the upper "Blaine of Texas."

A short digression from the discussion of the Custer is here necessary because the Falls of Salt Croton Creek is the result of a heavy ledge of dolomite over which the creek flows. This dolomite contains a rich ammonite fauna. Preservation is so splendid that accurate determinations have been made. As the age indicated is upper Leonard, the "Blaine of Texas" may now be chronologically classified. The value of this fossil locality lies in the fact that it is the only one so far discovered and as it has long been known in the literature it is unfortunate that it has been placed geographically in the wrong county.

The first citation of this locality is by Cummins.[18]

About one mile above the confluence of the Salt Croton Creek with the Salt Fork of the Brazos are the falls of Croton Creek. The water has a fall of about six feet. . . . The fossils recognized were two species of *Ammonite*, *Orthoceras*, and *Pleurophoras*. The upper part of No. 2 of the above section was almost entirely composed of *Ammonites?*.

1.	Blue clay	4 feet
2.	Limestone in layers, fossiliferous	8 feet
3.	Massive white gypsum	30 feet
	Total	42 feet

With the report by Cummins is a very primitive map of West Texas [Plate XVIII opposite page 552]. It shows in the southeastern part of King County a creek called Salt Fork of Croton Creek which enters the Salt Fork of the Brazos River in the extreme southeast

[18] W. F. Cummins, *Texas Geol. Survey Second Ann. Rept.* (1890), p. 408.

corner of King County. This is the only Croton Creek shown on the map. However, the locality of the section which Cummins measured is shown to be in the northwest corner of Stonewall County. This leaves some ambiguity as to the exact geographic location of the fossil locality.

The next citation of the locality is by Smith.[19]

> The Geological Survey of Texas found in Double Mountain formation at the falls of Salt Croton Creek, Kent County, Texas, *Medlicottia*, *Waagenoceras* and *Pleurophorus.*

These fossils were sent to Smith by the Geological Survey of Texas and probably the exact locality was misunderstood in correspondence. The geographic location of the streams is still in doubt. As a result several maps have been examined with the following results.

The United States Land Office base map for Texas shows in the southern part of King County, draining into the Salt Fork of the Brazos River, a North Croton Creek. The confluence is in the extreme northeast corner of Stonewall County. In the northwest side of Stonewall County is a Dove Creek which flows through the locality originally described by Cummins. About 12 miles south of Dove Creek is a Croton Creek also entering the Salt Fork of the Brazos River. There seem to be, therefore, two Croton Creeks and a Dove Creek.

The abstract map of the area shows Dove Creek entering the Salt Fork of the Brazos River in Sec. 123, Blk. F, H. & T. C. R. R. Co. Survey, while Croton Creek enters the Salt Fork of the Brazos River in Sec. 321 of the same block and survey. The geological map of Stonewall County published by the Bureau of Economic Geology, Austin, Texas, shows a Salt Croton or Kanawa Creek entering the Salt Fork of the Brazos River in Sec. 123, Blk. F, H. & T. C. R. R. Co. Survey. This is the creek which the United States Geological Survey calls Dove Creek, but the inhabitants of the area call it Salt Croton because salt is still gathered from it. The falls are on this creek. The creek which enters the Salt Fork of the Brazos River in Sec. 321 of the same block and survey is called Big South Creek.

CROTON FALLS SECTION

The following detailed section, cen. of Sec. 139, Blk. F., Houston & Texas Central R. R. Co. Survey, Stonewall County, Texas, shows the stratigraphic sequence at Croton Falls. The section begins just below the falls on Salt Croton or Kanawa Creek. Thence the section con-

[19] J. P. Smith, "Paleozoic and Mesozoic Border-Line," *Jour. Geol.*, Vol. 9, No. 6 (1901), p. 515.

tinues irregularly westward and ends at the top of the promontory in the SW., SE. of Sec. 159.

"TRIASSIC"

Custer

Feet	*Inches*	
		Orange polished eolian sandstone; interval not measured
Childress dolomite horizon		
1		Gypsum and anhydrite, white with pink laminations
20	8	Orange polished eolian sandstone, silt and grits

Unconformity

PERMIAN

"Blaine of Texas"

0	2	Soft reddish brown shale, ordinarily absent
Wagon Yard gypsum or Royston gypsum		
15		White gypsum and gray dolomitic gypsum; this is maximum thickness observed; bed is very prominent bench-former continuing many miles; locally removed due to unconformity above
60	10	Soft reddish brown shale; locally there are a few thin beds of gypsum 1–3 inches in thickness; interval ordinarily forms very steep slope
	4	Light gray blocky dolomite and gypsum; very local
6	8	Soft reddish brown shale with some thin beds of gypsum about 2 feet below top
10	9	As below with gypsum and selenite dikes
31		Interval consists of about 6 benches; each capped with gray dolomite, and gray gypsum or shale or both; benches separated by reddish brown shale
5	2	Reddish brown shale
5	2	Gray-green and reddish brown shale with 1–2-inch gypsum layers
5	2	Reddish brown shale with reddish brown-to-salmon gypsum and selenite
	10	Gray-to-buff silty dolomite; much greenish gray shale conglomerate associated with this dolomite; bed forms minor bench and contains many pelecypods, *Pleurophorus* sp.
13	6	Reddish brown shale; upper few feet of gray-green shale and selenite
10		Gray-green, white and salmon gypsum; bed very massive and blisters well developed on its surface.
2	6	Reddish brown shale
6		Massive white nodular gypsum
	10	Blocky light gray dolomite, very thin-bedded
	10	Greenish gray and ocher shale
2		Reddish brown shale and selenite
3–4		Greenish, reddish brown, and white gypsum with some reddish brown shale shells; greenish gypsum locally very persistent and about 1½ feet thick; on average about 2 feet above the dolomite
Aspermont or Guthrie dolomite		
6		Gray slabby dolomite; upper one-third is coquina; fossils forming this coquina occur in beds about 3 inches thick; main part of dolomite must have been deposited in rather shallow water; plentiful ripple marks and 2–3-inch beds of greenish shale conglomerates in dolomite matrix; great abundance of cephalopods and ammonites probably due to marine current moving fast enough to carry animals into environment alien to their existence, causing extinction; *Perrinites hilli* and *Eumedlicotta* sp. This bed has been mapped as Aspermont or Guthrie dolomite. It is doubtful if this correlation can be established as it is extremely local in mode of occurrence
1		Salmon-to-reddish granular dolomite, blocky to slabby; some dolomite has greenish cast
1–2		Fine gypsum conglomerate in greenish matrix; some of this material has reddish cast
3		Greenish gray blocky shale, gritty; brown and ocher colors near top
2		Mostly covered; some reddish brown shales exposed

Double Mountain which occurs in the southwestern part of Stonewall County, Texas, is a historic landmark and the detailed section of it, measured up the east and northeast flank, north side of Sec. 374, Blk. 2, H. & T. C. R. R. Co. Survey, is given here.

Feet	Inches	COMANCHE
Edwards limestone		
35		Gray hard crystalline limestone, fossiliferous, much Quaternary gravel on top, Comanche section below bed thins greatly toward west end of main outlier; no Edwards limestone on western outlier
Comanche Peak		
80		Light gray-buff chalk and gray marl; many oyster beds; upper 40 feet soft, lower part forms bench; this interval is 67 feet, 2 inches on west side of main outlier
50		Mostly yellow-ocher marl; very fossiliferous; oyster beds; marly interval about 20 feet thick; lower part reddish brown, maroon, olive-drab and ocher, micaceous coarse sandstone and conglomerate; white in places; contains many pink pebbles of metamorphic material; this interval 51 feet, 8 inches on west side of main outlier
Trinity sandstone		
62		Gray-buff and soft coarse conglomerate; pebbles mainly of metamorphic material, some of chert; some pebbles salmon-pink; some well worn fragments of petrified wood; much cross-bedding shown in conglomerate; top of Trinity may be slightly higher than here indicated; none of this material looks like Dockum as exposed in vicinity, but looks very much like Trinity as exposed in central Texas; this interval is 10 feet, 4 inches on west side of main outlier
		"TRIASSIC"
Custer		
15	6	Reddish brown soft but massive polished sandstone
67	2	Red-to-orange polished sandstone; some gray streaks due to leaching; 2-inch dolomite shell at top
5		Gray thin beds of anhydrite, gypsum encrusted
15		Reddish-to-orange polished sandstone; much selenite; reddish sandstone at top of interval
5		Anhydrite encrusted with gypsum
31		Orange polished sandstone, much harder near top; cementing material is dolomite and anhydrite
7		Crinkly anhydrite encrusted with gypsum
25	10	Dolomitic orange polished sandstone; well bedded in places; 2 main beds one at top and other at bottom
113	8	Orange polished sandstone with some selenite veins near base
15	6	Orange polished sandstone with anhydrite bed at base; this bed is about one foot thick and encrusted with gypsum; many selenite veins above anhydrite
41	4	Orange polished sandstone
		Base not exposed

This section of the Custer is essentially the same on both sides of the main outlier.

The base of the measured section is about 200 feet above the base of the Custer. The lower unmeasured section contains several thick beds of anhydrite, one of which is about 10 feet thick, and has been named the Oriana gypsum. Names have been given to these beds of anhydrite, but since their lateral extent is very limited no discussion of them is here presented. Double Mountain appears to be the

eastern extension of a regional synclinal feature, the axis of which continues to the southern part of Garza County. Medicine Mounds of Hardeman County also appears to be of a synclinal nature.

Patton,[20] in his discussion of the geology of Stonewall County proposes a new formation name, the Peacock. It includes all of the beds from the base of the Swenson gypsum up to the base of the Dockum. This definition is very unfortunate for several reasons: (1) even before leaving Stonewall County, Patton finds difficulty in recognizing and separating the Swenson from the other gypsums of the "Blaine of Texas," and as a result is led to postulate a sand bar;[21] (2) the separation and identification of the formation are based on a chemical facies; (3) since the Swenson gypsum belongs with the "Blaine of Texas" and furthermore is well down in the Blaine, any division would be extremely hazardous because of lateral variation; and (4) there is difficulty with the nomenclature as the geological map of the county published by the Bureau of Economic Geology at Austin, Texas, used the names Ward and Wagon Yard, while Patton has named them Oriana and Swenson, respectively.

Patton's definition of the Peacock formation as including all beds from the Blaine up to the base of the Triassic involves several difficulties as well as establishing priority. Gould long ago named the Woodward formation. In this formation he placed the following beds above the Blaine: the Dog Creek shale, Whitehorse sandstone, and Day Creek dolomite. Certain alterations have occurred in the sequence of these beds since Gould named the formation. Many geologists in Oklahoma now believe the Day Creek to overlie the Cloud Chief. The unconformity previously mentioned in the present paper occurs between the Whitehorse and the Dog Creek shale. Coming south in Texas to Stonewall County it is impossible to demonstrate whether the Quartermaster as now defined is present or not. Therefore, since Patton's Peacock formation by definition contains the same beds as Gould's Woodward, the Woodward formation clearly establishes priority.

Later in Gould's work in the Panhandle of Texas he established the name Quartermaster for all beds occupying the interval between the Blaine and the Triassic. Again we have the priority of the Quartermaster over the Peacock formation as it is now generally considered that the western Greer is equivalent to the Blaine.

It may be mentioned that since the base of the Peacock is drawn

[20] L. T. Patton, "The Geology of Stonewall County, Texas," *Univ. of Texas Bull. 3027* (1930).

[21] L. T. Patton, *op. cit.*, pp. 46–47.

MAP 9.—Fisher County, Texas.

at the base of the Swenson gypsum and since this gypsum is a considerable distance below the base of the unconformity and also due to the lateral variations, it is extremely difficult to carry the Swenson gypsum very far outside of Stonewall County; hence it is extremely difficult to define the base of the Peacock formation outside of Stonewall County.

FISHER COUNTY, TEXAS

From north to south across Fisher County, the unconformity at the base of the Custer progressively removes the "Blaine of Texas." In the extreme southern part of the county and near Eskota the Custer has almost reached the upper sandy facies of the San Angelo.

An interesting feature is the abundance of anhydrites and a thin dolomite which thickens southward, occurring at the base of the Custer. This dolomite is known as the Eskota and occupies the position of the Childress dolomite. Another feature of interest is the presence of a fine quartz conglomerate occurring at the base of the Custer in southern Fisher County and continuing southward to Coke County. The trace of the base of the Custer is rather irregular due to a major eastward drainage. Some measured sections will clarify the conditions of the contact.

In the central part of the north side of the county there is a great variation in the interval between the base of the Custer and the top of the "Wagon Yard" or "Ideal" gypsum. This duplication of names is used in the geologic map of Fisher County published by the Bureau of Economic Geology at Austin. Some consider the Ideal and Childress as being the same. Just above the base of the Custer occurs a 3-inch bed of gray dolomite which is the Eskota member. The Eskota is here associated with thick beds of anhydrite. In the center of the north side of Sec. 117, Blk. 1, H. & T. C. R. R. Co. Survey, the Custer rests on the "Wagon Yard" gypsum. In the SW. cor. of Sec. 92, same block and survey, the interval between the Custer and "Wagon Yard" is 25 feet of chocolate brown shale. In the southwest side of Sec. 99, the interval of shale is 44 feet. In the southeast corner of Sec. 100, the interval is 21 feet.

Cheney[22] has described a new formation which he calls the Royston formation. The town of Royston, the type locality, is in Sec. 331, Bastrop County School Land Survey. Since the type locality is located on the base of the Custer and since the formation is not delimited, it is doubtful if the name can be used with meaning.

[22] M. G. Cheney, "Stratigraphic and Structural Studies in North Central Texas," *Univ. of Texas Bull. 2913* (April 1, 1929), p. 26.

The measured section in Sec. 316, El Paso County School Land Survey, 2 miles east of Roby at T. road, is as follows.

Custer (Eskota dolomite member)

Feet	Inches	
	2–3	Dark gray blocky dolomite
6		Fine, orange polished sandstone
5	2	Orange polished sandstone with gypsum cement and some anhydrite
5	2	Fine, orange polished sandstone and grits
1		Leached polished sandstone with shells of anhydrite and gypsum
"Blaine of Texas"		
		Thin-bedded chocolate-brown shale with gray-green ½-inch dolomite shells; also alternating thin beds of gypsum and selenite with chocolate shale

The measured section at the gypsum plant just north of Longworth, SE. cor. of Blk. 318, Gillespie County School Land Survey, is as follows.

Custer

Feet	Inches	
		Sandy sepia and terra-cotta shales and anhydrites; interval not measured
	8	White anhydrite with pink laminations
	10	Orange polished sandstone and some fine quartz conglomerate and selenite
"Blaine of Texas"		
	18	Chocolate shale and selenite
10		Gypsum, white with grayish bands and trace of anhydrite at base
	3	Gray, ripple-marked dolomite

The section in the gulch on the west side of the road, 0.9 mile south of the northeast corner of Blk. 317, El Paso County School Land Survey, is as follows.

Custer (Eskota dolomite member)

Feet	Inches	
	4	Gray, blocky dolomite, pink when fresh
18	6	Fine, orange polished sandstone and terra-cotta shale
2		Gypsum and anhydrite; orange polished sandstone with anhydrite cement
5	2	Fine, orange polished sandstone
10	4	Orange polished grits with thin gypsum and anhydrite shells 1–2 inches thick
"Blaine of Texas"		
		Sepia-to-chocolate gritty shale with some thin gray dolomite shells

The type locality of the Eskota dolomite member is in the center of the north side of Sec. 232, W. L. Coulson Survey, just north of Eskota.

Custer

Feet	Inches	
		Immediately above the Eskota dolomite member are several beds of anhydrite and orange polished sandstone
Eskota dolomite member		
	12	Hard gray and blocky dolomite, pink and white laminations when fresh; ripple marked in places
22	8	Orange polished sandstone and grits with some terra-cotta shale; covered in most places
	15	Leached polished gray sandstone and fine quartz conglomerate

"Blaine of Texas"

Chocolate-brown shale, well bedded, contains thin beds of sandy gray-green dolomite, 1–2 inches thick; also thin veins of selenite

It may be seen from the previously given sections that the part of the section encountered below the Custer is extremely variable.

NOLAN COUNTY, TEXAS

Nolan County offers little of interest to the study of the Custer because, for the most part, the area is covered with the Comanche and Tertiary of the High Plains. In the northeast corner of the county the base of the Custer may be mapped for several miles. In the gypsum plant at Sweetwater, the anhydrites below the Eskota dolomite member rest directly on a heavy ledge of gypsum in the "Blaine of Texas." The contact may be found at the base of the fine quartz conglomerate cemented with anhydrite. In the pit the contact may be determined as being between the material which is used and that which is discarded.

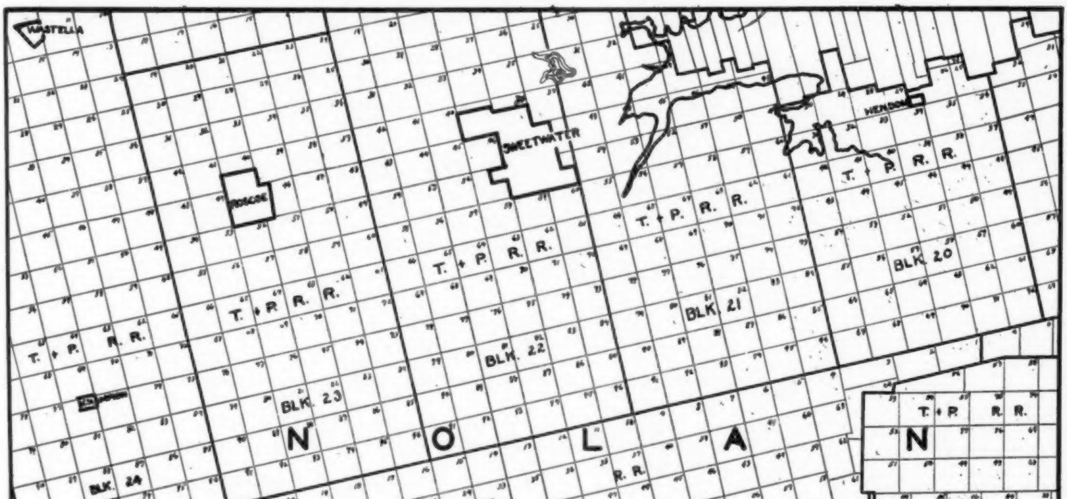
Eastward the Eskota dolomite attains a thickness of about 2 feet and is very blocky. The general appearance is similar to the Childress dolomite at the type locality. In the northwest part of Blk. 20, T. & P. R. R. Survey, the Custer rests on the upper sandy facies of the San Angelo, and when this occurs the exact contact is difficult to place without the aid of a microscope. As a result of this the mapped contact may be as much as 8 feet in error in some areas.

At Sweetwater Lake the Custer rests on chocolate-brown shales of the "Blaine of Texas." In this area some channeling may be noted; the channels are about a foot in depth.

On the south side of Nolan County and west of Blackwell it is possible that some beds of the Custer may crop out, although none is identified in the field. In this area there are very few roads and survey corners are hard to find.

Sweetwater is the type locality of the formation previously known as the Sweetwater-dolomite. This bed is about 250 feet stratigraphically above the base of the Custer. Cheney[23] proposes the name Claytonville dolomite after a town by that name in southwestern Fisher County for the pre-occupied Sweetwater dolomite. On the geological map of Fisher County published by the Bureau of Economic Geology, Austin, Texas, the name Claytonville has been used for a bed of anhydrite occurring approximately 200 feet below the dolomite previously called Sweetwater.

[23] M. G. Cheney, *op. cit.*



MAP 10.—Nolan County, Texas.

COKE COUNTY, TEXAS

In Coke County, just west of the town of Robert Lee, the base of the Custer is poorly exposed for several miles. Due to the lack of relief and to the fact that the base is in contact with the upper sandy facies of the San Angelo, the map is not considered accurate and may be in error as much as 10 feet stratigraphically in places. Both the north and south sides of the county are covered with Tertiary and Comanche sediment rocks of the High Plains.

The following section may give some idea of the contact. It was measured on the north side of the Colorado River and north of the bridge, just west of Robert Lee, Sec. 990, S. C. Rabb land of the S. A. M. Survey.

TERTIARY AND COMANCHE

"TRIASSIC"

Custer

Feet	
25	Orange polished sandstone and thin gray sandstone shells; terra-cotta shale, thin-bedded; all very soft
	Eskota dolomite member
1	Light gray, coarsely crystalline dolomite, very sandy and full of dark specks giving aspect of salt and pepper
5	Soft light gray-to-ocher polished sandstone and some fine quartz conglomerate

PERMIAN

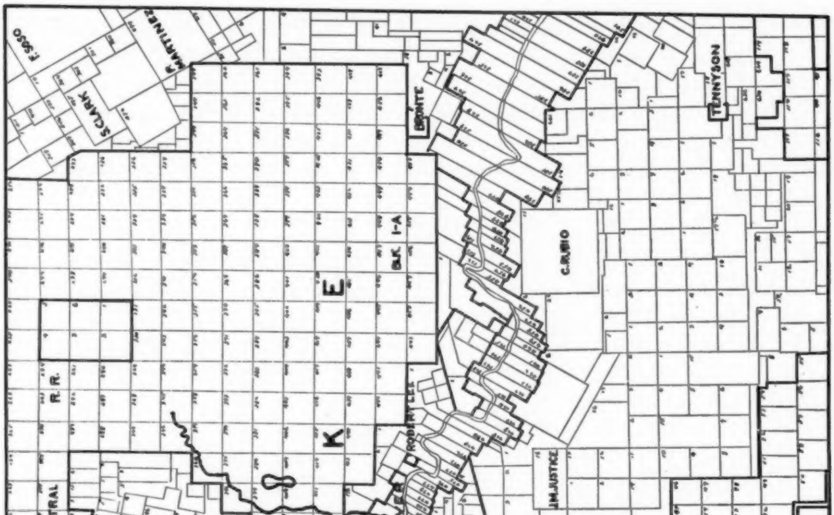
Upper San Angelo

Feet	
8	Orange sandstone and terra-cotta shale
5	Gray massive sandstone, very thin-bedded
3	Terra-cotta and chocolate-brown shale
5	Gray-to-orange red sandstone
5	Gray and brown sandstone, micaceous; green shale conglomerate at base with ocher-colored sandstone at top; ripple marked and very thin-bedded
17	Chocolate-brown shale; selenite bands and salt casts, thin sandy shells
10	Gray, leached, sandstone and grits, some ocher colors and very thin-bedded
20	Brown gritty shale and three beds of gritty sandy quartz conglomerate like next interval below; salt casts and selenite veins; micaceous
5	Fine, thin-bedded gray and gray-brown gritty sandstone. Conglomeratic as above and ripple-marked; bed pinches out laterally in less than 100 feet
10	Irregular-bedded gritty, reddish brown shale; many thin veins of selenite and many gray-green layers of shale; some chocolate-brown shale and gypsum

Colorado River

Beede[24] described some very thick beds of gypsum in the west side of the county. All of these beds have been found to be in the Custer with the exception of one bed of gypsum which occurs just above the Colorado River, 3 miles west of the town of Robert Lee. This gypsum bed is at the foot of Seaton Keiths Bluff and is the locality of the measured section here shown. The gypsum bed mentioned is below the base of the Custer. All the other massive so-called gypsum beds are anhydrite and are in the Custer. As yet they have no commercial value.

[24] J. W. Beede and W. P. Bentley, "The Geology of Coke County," *Univ. of Texas Bull. 1850* (1918).



MAP 11.—Coke County, Texas.

TOM GREEN COUNTY, TEXAS

The presence of beds probably belonging to the Custer has been reported in the mounds on the road between San Angelo and Fort Stockton. These mounds are approximately 5 miles west of San Angelo and occur on both sides of the highway. A careful investigation of these mounds has disclosed no sediments of Custer age. The sandstones in question are Comanche in age and do not have Custer aspects.

CONCLUSION

The foregoing pages have been written in the hope for a better understanding of those very interesting red-beds which immediately underlie the Upper Triassic of West Texas. The extreme lateral variation of the beds described in this article, when compared to those which underlie, leads to much confusion in regional correlations; hence the county maps may in a way be helpful to those interested in the area. If nothing else is accomplished by this work, at least it is hoped that a new vista of thought will be opened to the regional stratigrapher which may prove to be of economic value in the Permian basin of West Texas as well as western Oklahoma and western Kansas.

DISCUSSION

Ira Cram, Tulsa, Oklahoma (received, February 15, 1937): In the Anadarko basin of Oklahoma, Roth's Custer formation would include those sediments between the base of the Marlow formation and the Tertiary. In this area there are unconformities which separate the Marlow formation from the Rush Springs formation and the Rush Springs from higher sediments. These definite mechanical changes may or may not be recognizable in other areas, but their presence over several counties in Oklahoma certainly satisfied every requirement for dividing the Custer unit into formations. It is probable, therefore, that the Custer can not be correctly termed a formation because it contains within its boundaries perfectly good formations. The term Custer is an Oklahoma term and the Oklahoma conditions are, therefore, most important. Considering these factors, we believe the Custer unit is correctly classified as a group.

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SPINDLETOP OIL FIELD, JEFFERSON COUNTY, TEXAS[1]

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Houston, Texas

ABSTRACT

The major oil production at Spindletop now comes from the south, southwest, and west flanks of the dome. The oil is found in the Middle and Lower Miocene and to some extent in the Middle Oligocene formations. The sands are very lenticular and irregular, and can not be correlated from well to well, rarely even in the case of two adjoining wells. The Spindletop field has been an extremely prolific producer. The old cap-rock area has produced approximately 50 million barrels of oil and the new flank area through 1936 has produced approximately 75 million barrels of oil. Detail cross sections of the dome suggest the possibility of overhang. If this is true, the dry flanks of the dome may yet offer the possibility of future production.

LOCATION

The Spindletop oil field is located in the J. A. Veatch and P. Humphrey leagues, northeastern Jefferson County, Texas, about 2 miles south of Beaumont and approximately 40 miles from the coast.

HISTORY

The spectacular discovery of the Spindletop oil field by the Lucas wild gusher on January 10, 1901, marked the opening of one of the greatest and most famous oil fields in Gulf Coast oil history. The details of the persistent efforts of Patillo Higgins and Captain Lucas to find oil at Spindletop prior to this well have been given by Barton and Paxson[4] and many other authors.[5] It is not the purpose of this article to repeat or enlarge on this stage of Spindletop history, but rather to discuss the extraordinary flank development that started early in 1926.

Following the Lucas gusher, the drilling of the cap-rock area proceeded in profligate haste amid the attendant trials and tribula-

[1] Manuscript received, February 18, 1937. Read before the Association at Los Angeles, March 18, 1937.

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[4] D. C. Barton and R. B. Paxson, "The Spindletop Salt Dome and Oil Field, Jefferson County, Texas," *Geology of Salt Dome Oil Fields* (Amer. Assoc. Petrol. Geol., 1926).

[5] Thelma Johnson and others, *The Spindletop Oil Field, A History of Its Discovery and Development*, Neches Printing Company (Beaumont, Texas, 1927).

tions of the wildest boom. One great gusher followed another as the prolific cap-rock cavernous dolomite was entered by the drill. By October, 1901, there were 65 flowing wells equal to the discovery well, or capable of producing 60,000–80,000 barrels daily. A partial list of these wells is given in Table I and is of interest chiefly in the many names that it contains of men and companies familiar to the oil industry of that day. Out of about 132 oil companies operating at Spindletop in 1901 only a few have come down to the present time. Most prominent among these are undoubtedly the four major oil companies, The Texas Company, the Gulf Oil Corporation, the Sun Oil Company and the Magnolia Petroleum Company.

TABLE I

RECORD OF SPINDLETOP GUSHERS

(Published, October, 1901)

On Spindletop Heights there are now 65 gushers, any one of which is equal to the famous "Lucas geyser." The following is a partial list of gushers with the date of their coming in.

1. Lucas	January 10, 1901	Guffey Company
2. National (Beatty)	March 26, 1901	National Oil and Pipe
3. McFaddin No. 1	March 29, 1901	Guffey Company
4. Gladys No. 1	April 3, 1901	Guffey Company
5. Higgins No. 1	April 16, 1901	Higgins Company
6. Gladys No. 2	April 8, 1901	Guffey Company
7. Heywood No. 1	April 18, 1901	Heywood Company
8. Gladys No. 3	April 26, 1901	Guffey Company
9. Star and Crescent	May 3, 1901	Lone Star and Crescent Company
10. Gladys No. 4	May 8, 1901	Guffey Company
11. Heywood No. 2	May 25, 1901	Heywood Company
12. McFaddin No. 3	May 26, 1901	Guffey Company
13. McFaddin No. 2	May 27 1901	Guffey Company
14. Heywood No. 3	June 24, 1901	Heywood Company
15. Hogg-Swayne No. 1	June 26, 1901	Hogg-Swayne Syndicate
16. Higgins No. 2	June 30, 1901	Higgins Company
17. Columbia	July 11, 1901	Columbia Oil Company
18. National No. 2	July 22, 1901	National Oil and Pipe Company
19. Spindle Top	July 31, 1901	Spindle Top Oil Company
20. Ground Floor	July 31, 1901	Ground Floor Company
21. Gladys No. 5	August 2, 1901	Guffey Company
22. Yellow Pine	August 2, 1901	Yellow Pine Company
23. Cox-Josey	August 7 1901	Not Incorporated
24. Manhattan	August 8, 1901	Manhattan Oil Company
25. Darragh	August 9, 1901	Manhattan Oil Company
26. Cattlemen's	August 9, 1901	Cattlemen's Consolidated Oil Company
27. Beatty No. 2	August 15, 1901	Beatty Oil Company
28. Alamo	August 18, 1901	Alamo Oil Company
29. National No. 3	August 19, 1901	National Oil and Pipe Line
30. El Beaumont	August 18 1901	El Beaumont Oil Company
31. Export	August 16, 1901	Export Oil and Pipe Line Company
32. Fountain Fuel	August 22, 1901	Fountain Oil and Fuel Company
33. El Paso	August 23, 1901	El Paso Oil Company
34. Merchants	August 25, 1901	Joint Well Merchants and Mechanics-Spangler

35. Beaumont and Palestine	August 24, 1901	Palestine and Beaumont Oil Company
36. Miss-Texas	August 27, 1901	Miss-Texas Oil Company
37. Gladys No. 6	August 28, 1901	Guffey Company
38. Chaison No. 1	August 27, 1901	Guffey Company
39. Fagin	August 30, 1901	Grace Federal Crude Oil Company
40. Fort Worth	August 30, 1901	Fort Worth Oil Company
41. M.K. & T. of Beaumont	August 30, 1901	M. K. & T. Oil Company
42. Drillers	August 30, 1901	Drillers' Oil Company
43. Beaumont Confed.	August 30, 1901	Beaumont Confed. Sts. Alleys
44. Buffalo	September 1, 1901	Buffalo Oil Company
45. Gober	September 3, 1901	Gober Oil Company
46. Moore-Skinner	September 7, 1901	Lucky Dime, Gladys, Ent., Victor
47. Georgetown-Waco	September 9, 1901	Georgetown-Waco Company
48. Oteri	September 13, 1901	
49. Eureka	September 14, 1901	Eureka Oil Company
50. Geyser-Kaltenbach	September 14, 1901	Geyser Oil Company
51. Trenton Rock	September 16, 1901	Trenton Rock Oil Company
52. Queen of Waco	September 18, 1901	Queen of Waco Oil Company
53. Star and Crescent	September 19, 1901	Star and Crescent Company
54. German-American	September 21, 1901	German-American Oil Company
55. King	September 23, 1901	King Oil Company
56. Paragon	September 23, 1901	Paragon Oil Company
57. Detroit-Beaumont	September 24, 1901	Detroit-Beaumont Oil Company
58. Alamo	September 24, 1901	Alamo Oil Company
59. Cincinnati-Beaumont	September 24, 1901	Cincinnati-Beaumont Oil Company

The cap-rock area in Spindletop reached its greatest annual production in 1902. It produced that year nearly 17½ million barrels. There was a steady and continuous decline until 1925, when the annual production reached only 412,000 barrels. The development of the southwest flank of the dome in 1926, however, raised production to a new high of more than 21 million barrels in 1927. For the year 1936 the field produced over 800,000 barrels, and the total production for the entire field through 1936 has been in excess of 124½ million barrels.

As the flush production of the cap-rock field was being progressively drained interest turned to the possibilities of flank production. The Gulf Production Company in 1918 attempted deep development but without success. Marrs McLean of Beaumont in 1920 and the Rycade Oil Company in 1921 failed in flank tests. In 1925, the Yount-Lee Oil Company, of which Miles Frank Yount of Beaumont was the active head, undertook finding deep production. This company's Gladys City No. 1 and McFaddin No. 1 were both dry. The McFaddin No. 2 due south of and just off the salt plug, discovered rich commercial flank production in early 1926 and opened the new or "second" Spindletop oil field.

The summer of 1926 and the following winter witnessed the second great Spindletop boom. The enormously rich productive area was

rapidly extended westward, northwestward, and eastward from the discovery well. Production reached a figure of 100,000 barrels daily for the late summer and early winter months. Lease prices advanced to new all-time highs and drilling sites were so congested that in places derrick floors were joined as a continuous platform. The Gulf, Atlantic, Sun, and Rio Bravo were among the chief operators in addition to the Yount-Lee Company.

The major part of the new field, however, was in the hands of one operator, the Yount-Lee Company, and an orderly development was arranged. This program was interrupted by the untimely death in 1933 of Yount while still a comparatively young and active man. The properties of the Yount-Lee companies including all the Spindletop holdings were eventually, in 1935, sold to the Stanolind Oil and Gas Company, and the continued orderly exploration and development of the flank was again assured.

PHYSIOGRAPHY

The topography of the Spindletop dome area is shown by the map, Figure 1, which outlines a more or less circular mound. The one-foot contours indicate that the maximum relief of the hill is 16 feet, the top of the hill reaching 27 feet above sea-level. One mound is steepest on the south and slopes more gradually toward the north. It overlies generally the salt stock of the dome. The location of the Lucas discovery gusher is indicated on the topographic map.

SURFACE GEOLOGY

The Beaumont clays of Pleistocene age are exposed on the surface at Spindletop, around the flanks of the dome and in the adjacent prairies. The clays range in color from dark gray to black. The mound proper is covered by a layer of buff sand which is identified as belonging in the Beaumont formation. This sand stratum ranges from 5 to 15 feet thick from the top of the dome to where it is covered by the clays.

STRATIGRAPHY

In the development of the new flank production at Spindletop the wells were drilled so quickly and without regard to paleontological data, that very few samples were saved on few wells which unfortunately deprives the industry of such data from the majority of the wells. Nevertheless, the samples that were available afforded a means of formulating a fairly representative stratigraphic section of the formation penetrated in the development of the new Spindletop oil field.

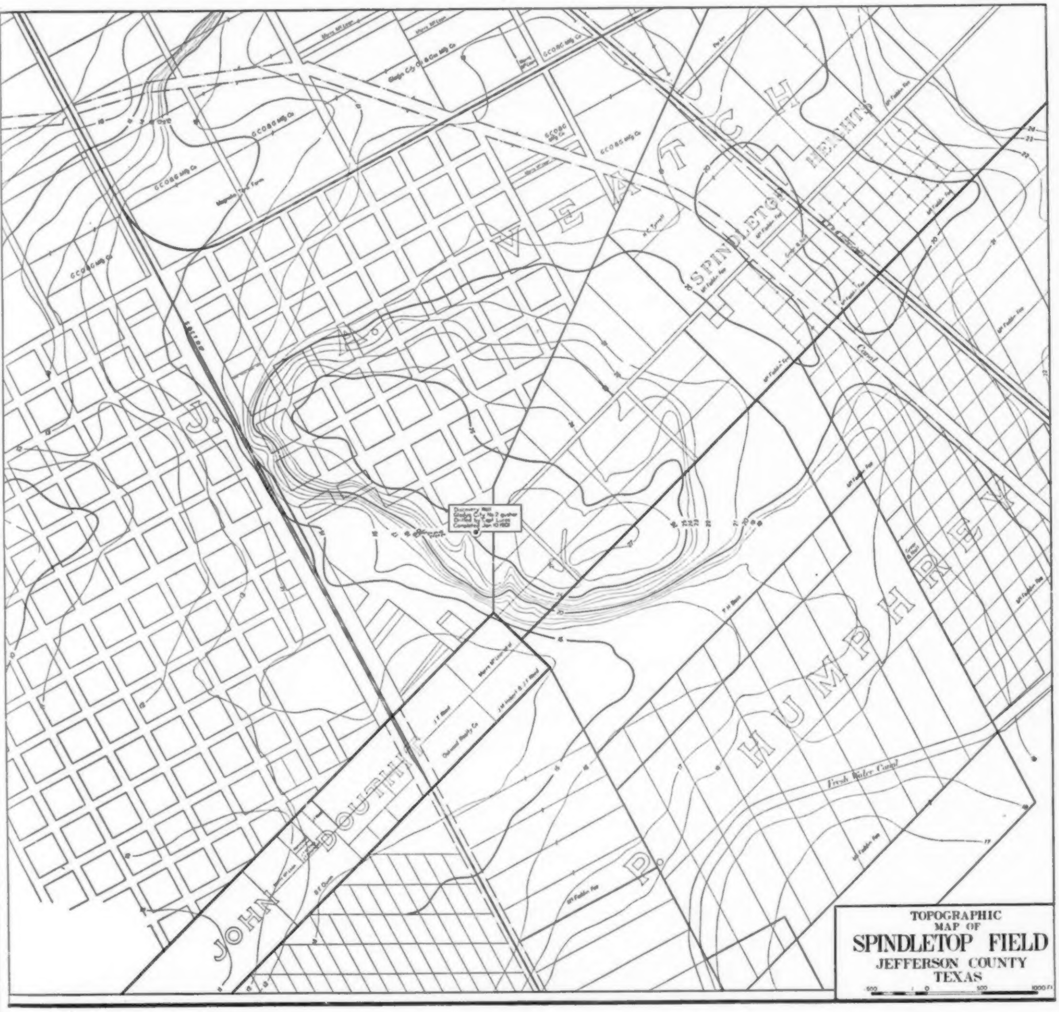

FIG. 1.—Topographic map of Spindletop field, Jefferson County, Texas.

The Beaumont formation ranges in thickness from 30 feet to 80 feet and is composed of dominantly gray-to-black clays with one main stratum of buff coarse-to-medium-grained sand lying under the first break of clay. No other sand bodies exist in the Beaumont formation. The clays lie immediately above the Lissie formation.

The Lissie formation of Pleistocene age is identified easily by the first coarse sand and/or gravel stratum that exists underneath the Beaumont clays. The formation is characterized by sands and gravels, associated together, definite bodies of medium-to-very coarse-grained sand, a few layers of soft shale and sandy shale, with small-to-large boulders intermingled throughout the entire formation. The water sands are plentiful in this formation and were successfully shut off by setting surface casing. The Lissie formation off of the super-dome structure is from 1,100–1,300 feet thick.

The Upper Pliocene formation, which is referred to as the Citronelle, is dominantly calcareous shales and limestones. A few thin sand bodies are also present in this formation but are extremely mucky and shaly, and are much more fine-grained than the upper sands of Lissie age. The Citronelle ranges in thickness from 200 feet to 300 feet depending on the distance away from the super-dome structure.

The Lower Pliocene formation or upper Fleming is composed of indurated sandstone, limestone, and tough shales. Very few sand bodies exist in this formation. The upper Fleming is 200–400 feet thick.

The Miocene formation or lower Fleming is composed of light-to-dark green compact shales and many bodies of fine-to-medium-grained sand. Except for a few Middle Oligocene wells, all of the new production is from this formation. The formation is composed of a continuous series of sands and compact shales. The thickness of the Miocene is 2,200–3,000 feet.

The Oligocene formation is represented at Spindletop by the *Discorbis*, *Heterostegina*, and *Marginulina* zones. These zones were definitely recorded by paleontological determination. They are grouped under the Middle Oligocene formation. The *Discorbis* zone is identified by the appearance of dark green shales and the presence of the *Discorbis* fauna characterized by *Discorbis* cf. *D. vilardeboana* D'Orbigny. A few thin bodies of sand are also present in this zone. The zone ranges in thickness from 200 feet to 600 feet.

The *Heterostegina* zone is composed of compact calcareous shales, limestones, and few sand layers, and which is identified paleontologically by the typical *Heterostegina* zone *Foraminifera*, characterized

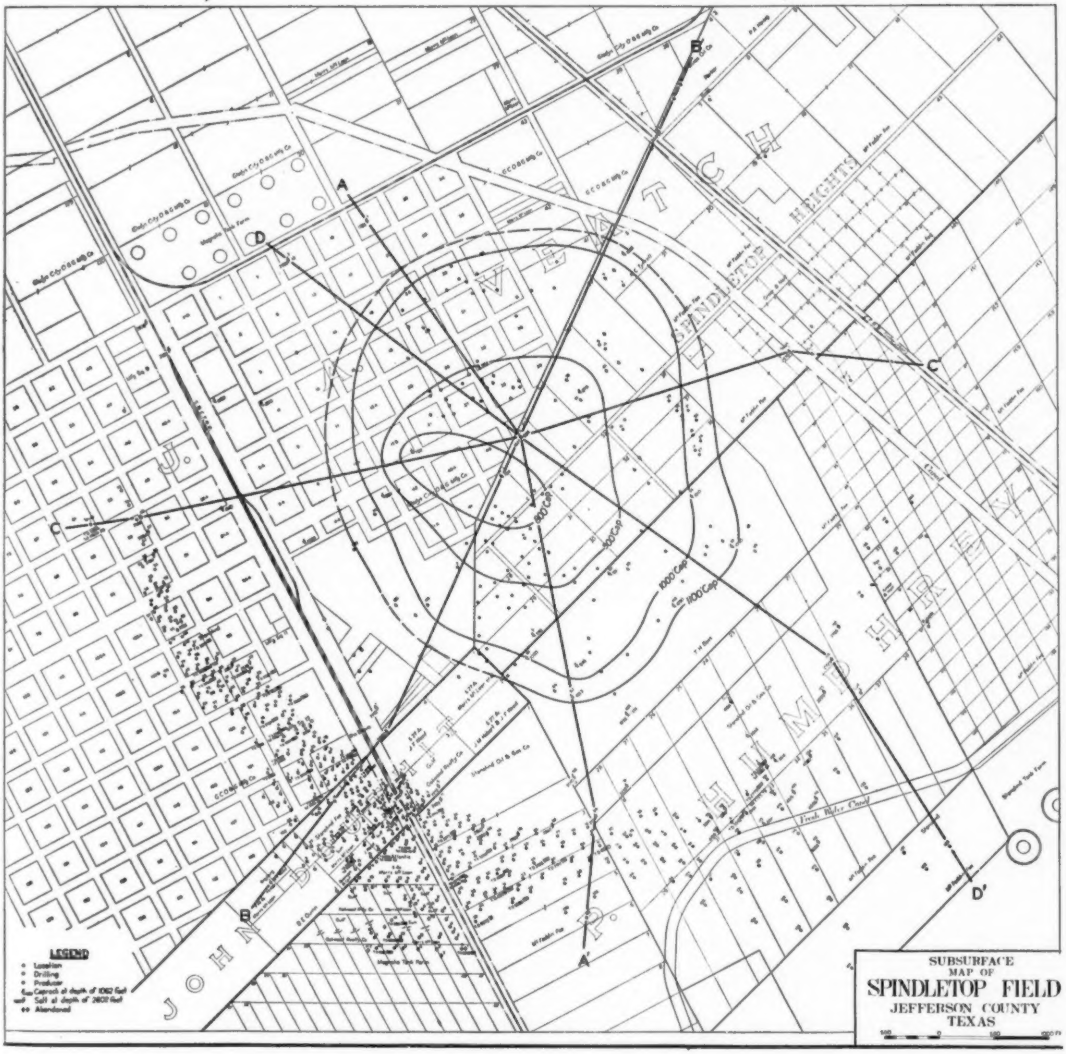

FIG. 2.—Subsurface map of Spindletop field, Jefferson County, Texas. Contours based on top of cap rock. Cross-section lines from which profiles of dome were drawn are shown.

by *Heterostegina* cf. *H. antillea*. The zone ranges from 100 feet to 350 feet thick.

The *Marginulina* zone in most places is composed of dark green shales with practically no sand breaks and is definitely identified by the presence of the *Marginulina* zone *Foraminifera*, characterized by *Marginulina* cf. *M. philippenensis*.

No definite record has been available to the writers to suggest that the entirety of the *Marginulina* zone has been penetrated and that Lower Oligocene strata have been entered. It is believed by the writers that as yet no Lower Oligocene strata have been encountered.

A typical section and thickness of the formation on the flanks of the Spindletop dome is shown in Table II.

TABLE II

TYPICAL SECTION, FLANKS OF SPINDLETOP OIL FIELD

System	*Formation*	*Zone*	*Lithological Character*	*Thickness in Feet*
Pleistocene	Beaumont clays		Gray and black clay, sandy loam	30–80
	Lissie sands and gravels		Sands and gravels, boulders	1,100–1,300
Pliocene	Citronelle		Calcareous shales and limestone	200–300
	Upper Fleming		Sandstone, limestone, and tough calcareous shales	200–400
Miocene	Lower Fleming		Green compact shales, sands, sands and shales	2,200–3,300
Oligocene	Middle Oligocene	*Discorbis*	Shale, little sand	200–600
		Heterostegina	Shale, little sand	100–350
		Marginulina	Shale, little sand	400–(?)
	Lower Oligocene	Frio		(No penetration)
		Vicksburg		(No penetration)

SUBSURFACE GEOLOGY

The geology of the cap rock at Spindletop was explained in detail by Barton and Paxon's earlier paper. However, Figure 2 is a subsurface map showing the contours based on top of the cap rock. This figure also shows the cross-section lines from which profiles of the dome were drawn. From the contours based on the cap rock it is apparent that the dome is elongated with a southeast-northwest trend. This position of the dome is also borne out by the contours based on the salt (Fig. 3). This elongation of the dome in one direction seems

Fig. 3.—Subsurface map of Spindletop field, Jefferson County, Texas. Contours based on salt. Cross-section lines show where profiles of dome were drawn.

to be of a significant and important value. By observing the horizontal extent of production it is conclusive that the most prolific production has been found on the south, southeast, and southwest flanks of the dome. It is evident that the oil has "banked" against the south side of the dome, and gradually diminished southeast and northwest. No flank production has yet been found in any appreciable commercial quantities from the northwest, north, northeast, and east flanks.

It is the writers' belief that careful and extensive drilling on those flanks would eventually prove profitable.

The productive sands at Spindletop were found to be broken and in lenses. Even though in many wells that were completed at approximately the same depth, the sands would be of different character and produce various grades of oil which proved the existence of numerous lenses and broken sand bodies. Correlation on top of any producing sand is very difficult.

In Figure 4, which is a southeast-northwest cross section, the various positions of the formation and shape of the dome are illustrated. The formations have been found to have steep dips near the "knee" of the dome, and gradually the dips become less at greater depth. This particular observation has led the writers to believe that an overhang exists at Spindletop and they have drawn the cross section to show a slight overhang, although they believe that the horizontal extent of the overhang will be several hundred feet. The underneath divergence of the salt contours (Fig. 3) on the southeast, south, west, and northwest flanks, also supports the idea that an overhang exists, because such divergence of contours on proved overhanging domes is already known to be of significance to an overhang.[6] The Stanolind Oil and Gas Company's McFaddin No. 71 (drilled by Yount-Lee Oil Company), which was drilled to a depth of 4,050 feet without striking the salt (Fig. 4) and the Gladys City No. 71 (Fig. 6) drilled on the west flank to a depth of 5,524 feet without penetrating the salt, also tend to reveal that the dome swings inward instead of continuing with a regular dip outward, thus forming an overhang. It is highly probable that the overhang is completely around the dome and that future drilling will prove its existence.

Production on the present dry flanks may be prolific by overhang production.

Figure 5 is a cross section showing the productive Miocene sands

[6] M. T. Halbouty, "Geology and Geophysics Showing Cap Rock and Salt Overhang of High Island Dome, Galveston County, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 20, No. 5 (May, 1936), Figs. 26 and 27.

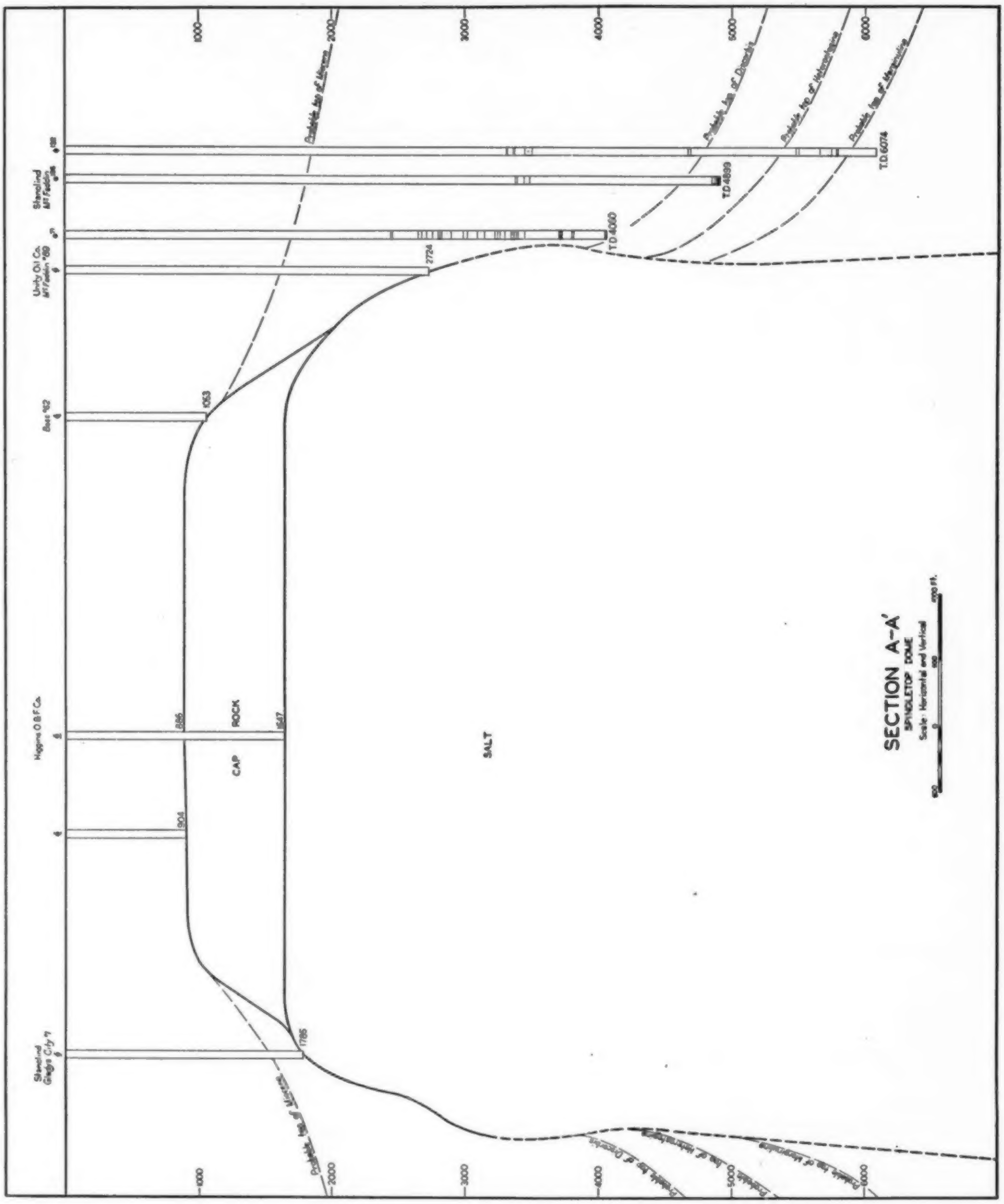

FIG. 4.—Southeast-northwest cross section of Spindletop dome, showing various positions of formation and shape of dome.

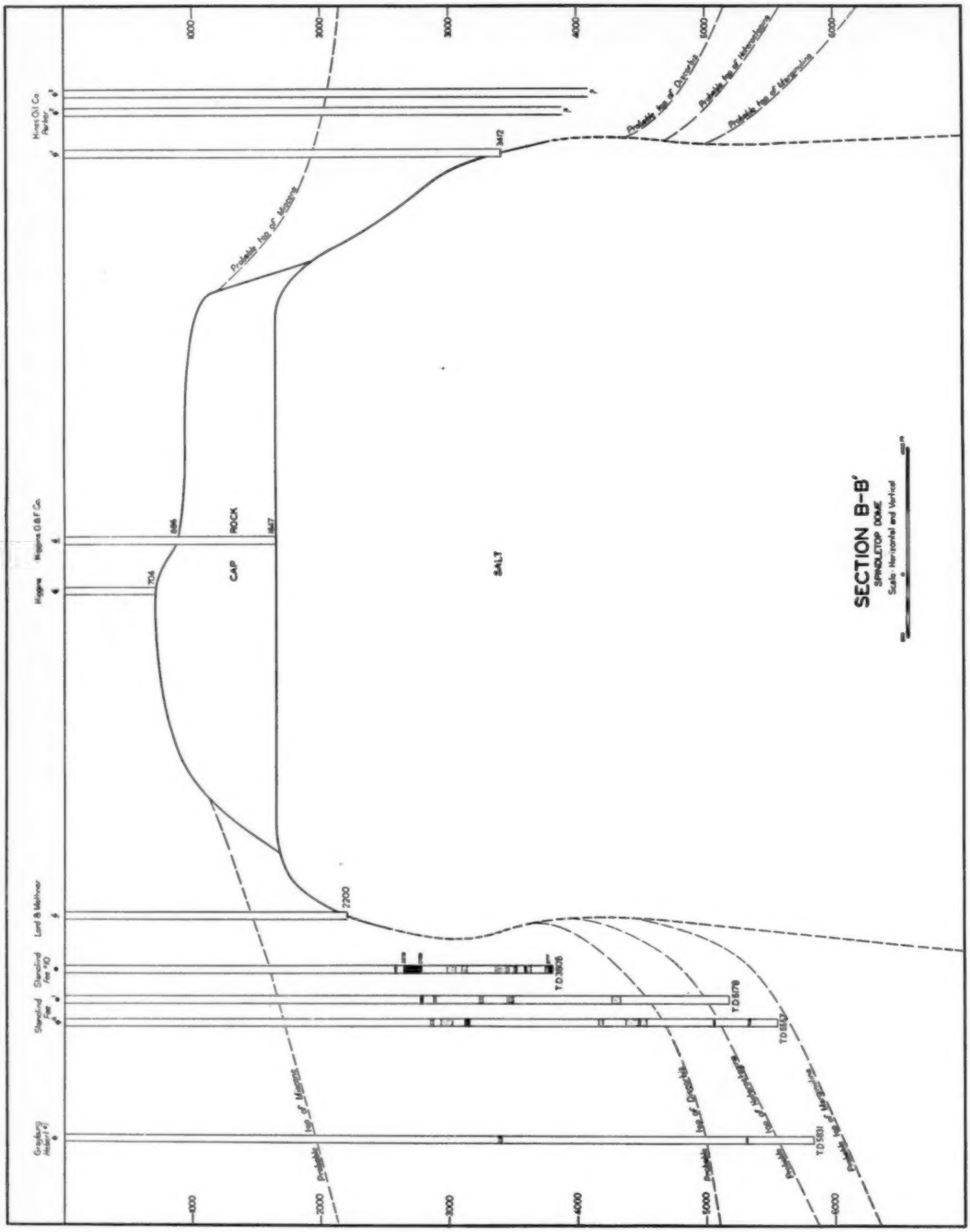

FIG. 5.—Northeast-southwest cross section of Spindletop dome showing productive Miocene sands on southwest flank of dome.

FIG. 5.—Northeast-southwest cross section of Spindletop dome showing productive Miocene sands on southwest flank of dome.

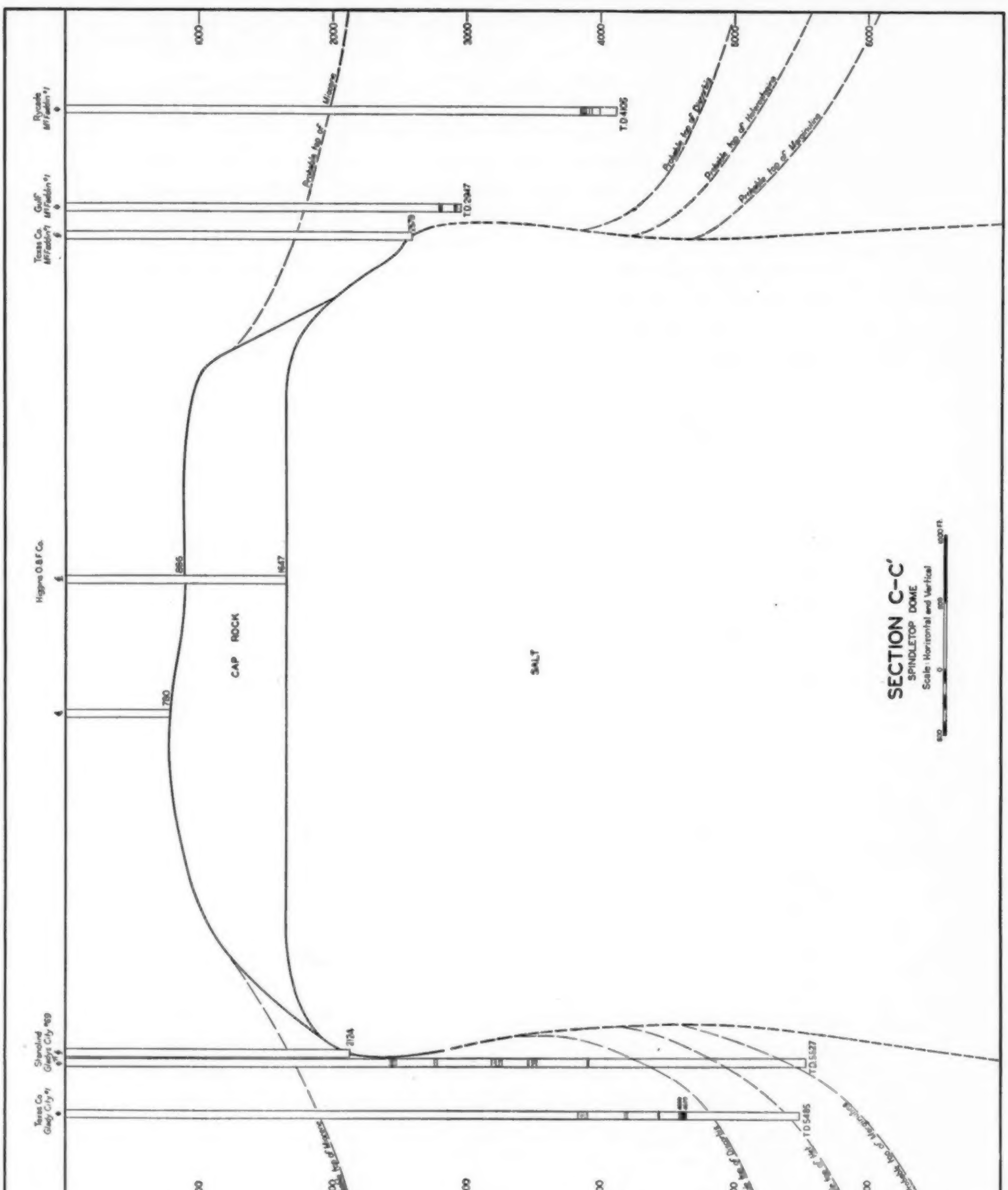

FIG. 6.—Northeast-southwest cross section of Spindletop dome showing how dome swings inward instead of continuing with a regular dip outward, thus forming an overhang.

on the southwest flank of the dome. This particular flank is the most prolific of all the flanks' new production. One lease alone, a 10-acre Stanolind Fee lease which this cross section cuts, produced over a million barrels of oil per acre.

The thickness of the productive sands is 10 to 210 feet.

The Middle Oligocene zones carried stray sands which were saturated with oil and high gas pressure. The *Discorbis* zone sands were not very thick but were productive in several wells. The *Heterostegina* and *Marginulina* sands were also thin and a few wells were made in the *Heterostegina* zone but none has been recorded as producing from the *Marginulina* zone.

Faulting is apparent on the south flank; however, lack of paleontological data forbids any postulating as to the position of the faults.

The areal extent of production has been limited on the flanks, as a study of Figure 3 will show. Beginning from the northwest flank and following in a counter-clockwise direction, the horizontal extent of the production begins within a few feet of the outer flank of the salt and increases to 600 feet in a peripheral distance of 1,600 feet, and finally to a horizontal extent of 1,400 feet on the south flank, then dwindles down to nothing again on the east flank. The flank area of deep production at Spindleton contains 150 acres, the old cap-rock area 280 acres.

The gradual broadening of the horizontal extent of the production to a point of 1,400 feet maximum on the south flank clearly indicates that the oil has "banked" against the flat side of the dome, and that as the apex points of the elongation are reached the horizontal extent of the production diminishes.

CHARACTER OF OIL

In the new flank production there are four types of oil that have been found. Two types have been found in the Middle Miocene, one type in the Lower Miocene and another type in the Oligocene sands. Type "A" and type "B" will be referred to as from the Middle Miocene, type "C" from the Lower Miocene, and type "D" from the Oligocene. These types have been described by Barton[7] in great detail. Type "A" oil ranges in gravity from 25.7°A.P.I. to 29.1°A.P.I. and is obtained from a depth of 2,715–3,305 feet. Type "B" oil ranges in gravity from 25.6°A.P.I. to 28.9°A.P.I. and the sands from which this oil is obtained range in depth from 2,785 feet to 3,377 feet. Type "C" oil ranges in gravity from 29.5°A.P.I. to 30.4°A.P.I. and the

[7] Donald C. Barton, "Variation and Migration of Crude Oil at Spindletop, Jefferson County, Texas," *Gulf Coast Oil Fields* (Amer. Assoc. Petrol. Geol., 1936), p. 309.

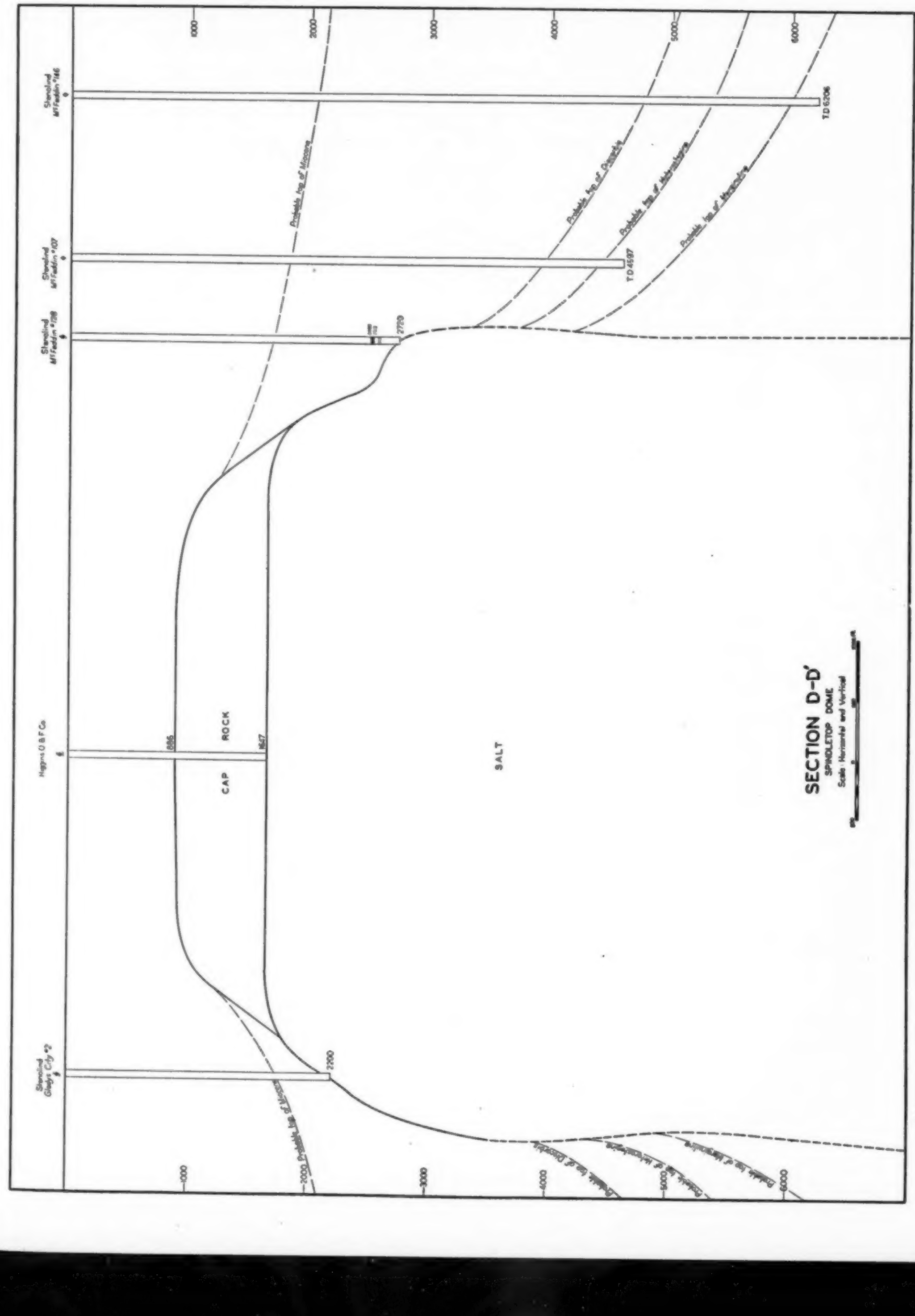

FIG. 7.—Northwest-southeast cross section of Spindletop dome, Jefferson County, Texas.

depth from which this oil is obtained is 3,340–5,003 feet. The Oligocene oil, type "D" oil, is of 29.7° and higher gravity and is obtained at the lower depth. In different horizons of similar depths the gravity of the oil differs from 2° to 3°. This particular observation is brought out to prove that the sand conditions existing on the flanks of the dome at Spindletop are not continuous but are broken and in lenses.

TABLE III

PRODUCTION OF PETROLEUM IN SPINDLETOP FIELD, BEAUMONT, TEXAS

1901 to and including December 31, 1936

Year	*Barrels o Production*
1901	3,593,000
1902	17,421,000
1903	8,601,000
1904	3,438,000
1905	1,653,000
1906	1,077,000
1907	1,700,000
1908	1,747,000
1909	1,388,000
1910	1,182,000
1911	966,000
1912	823,000
1913	716,000
1914	580,000
1915	388,000
1916	341,000
1917	380,000
1918	557,000
1919	407,000
1920	322,000
1921	344,000
1922	289,000
1923	326,000
1924	359,000
1925	412,000
1926	15,040,667
1927	21,264,935
1928	14,332,357
1929	10,183,684
1930	5,997,913
1931	3,205,994
1932	1,442,560
1933	1,168,432
1934	1,149,625
1935	942,913
1936	841,800
Total	124,580,880

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VOL. 21, NO. 4 (APRIL, 1937), PP. 491-499, 7 FIGS.

MIOCENE, PLIOCENE, AND PLEISTOCENE FORMATIONS IN RIO GRANDE REGION, STARR AND HIDALGO COUNTIES, TEXAS[1]

ALBERT W. WEEKS[2]
Wichita Falls, Texas

ABSTRACT

The upper Catahoula, Oakville, Upper Lagarto, Lissie, Leona, Beaumont, and Reynosa caliche deposits along the Rio Grande, through Starr and Hidalgo counties, Texas, are mapped and described. This paper supplements an earlier one.[3]

INTRODUCTION

During the latter part of 1934 the writer did some geological work in the Rio Grande region, principally between Rio Grande City, Starr County, and McAllen, Hidalgo County, and northward in these counties (Figs. 1 and 2). The generalized results of this work are presented in this paper, a supplement to an earlier one by the writer, discussing the younger deposits of the coastal plain section between Brazos River and the Rio Grande.[4]

CATAHOULA FORMATION

Excellent exposures of Catahoula are present along the paved highway and also along the old military gravel road from Rio Grande City eastward to approximately 5 miles of the Starr-Hidalgo county line (Fig. 2). About 4½ miles east of Rio Grande City, and west of the brick plant, gray sandstone of Catahoula age is exposed directly north of the highway. From this point eastward to the overlying Oakville in eastern Starr County, the Catahoula is composed of white-to-gray, green, pink, and varicolored ash and tuffaceous clay. A typical exposure of Catahoula, overlain by Lissie gravel, is shown in Figure 4.

[1] Manuscript received, January 26, 1937.

[2] District geologist, Shell Petroleum Corporation.

For permission to publish this paper, the writer is indebted to the management of the Shell Petroleum Corporation and especially to W. Van Holst Pellekaan and Roy R. Morse. Appreciation is expressed to W. H. Twenhofel who read and criticized the manuscript.

[3] Albert W. Weeks, "Lissie, Reynosa, and Upland Terrace Deposits of the Coastal Plain of Texas between Brazos River and Rio Grande," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, No. 5 (May, 1933), pp. 453-87.

[4] *Ibid.*, pp. 453-87.

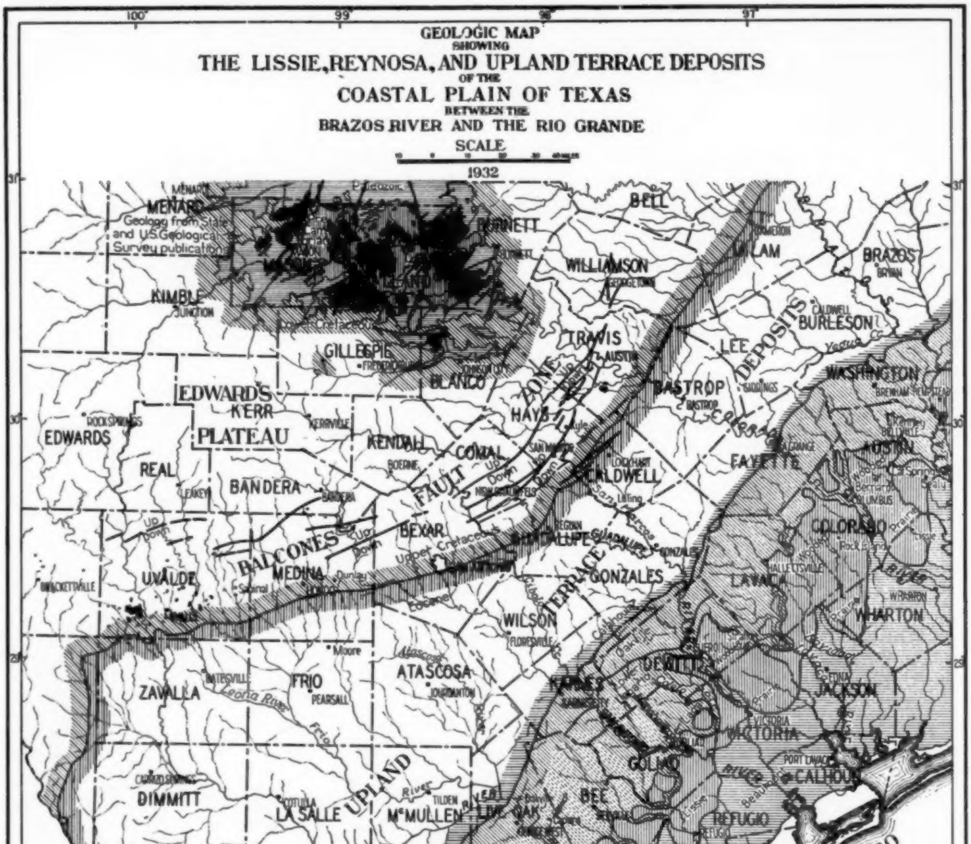

FIG. 1.—Geologic map showing Lissie, Reynosa, and Upland Terrace deposits of Coastal Plain of Texas between Brazos River and Rio Grande.

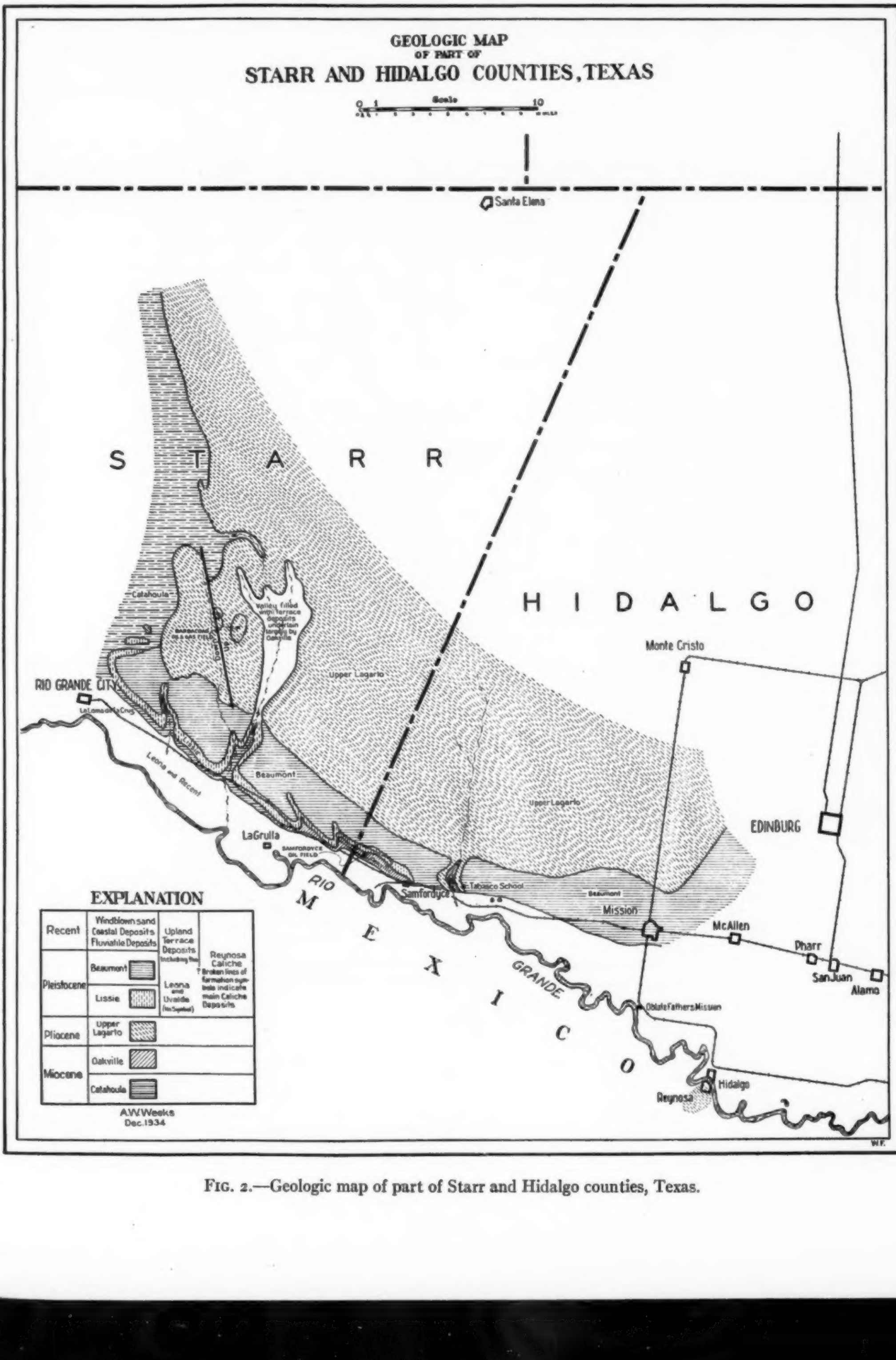

FIG. 2.—Geologic map of part of Starr and Hidalgo counties, Texas.

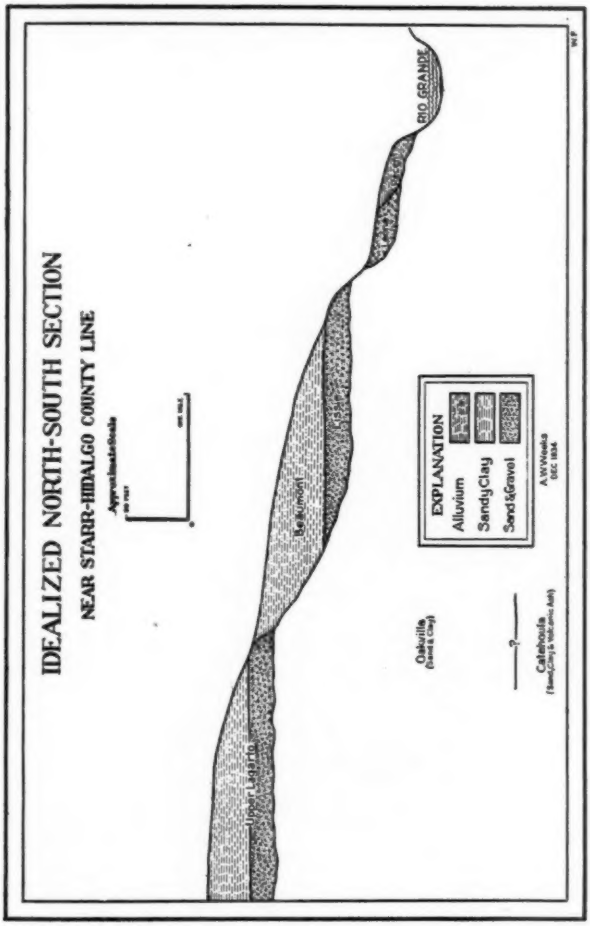

FIG. 3.—Idealized north-south section near Starr-Hidalgo county line.

On the basis of contained vertebrate fossils, the age of the Catahoula is believed to be Miocene.[5]

OAKVILLE FORMATION

From eastern Starr County eastward along the main highway and south of it, gray and yellow Oakville sandstone and clay are well exposed at various points as far east as La Joya Lake directly west of Tabasco School in Hidalgo County and approximately 6 miles east of the west line of the county (Fig. 2).

The sandstone forming the hill on which the Oblate Fathers' Mission is situated, about 4 miles south of the town of Mission, is probably of Oakville age. Typical exposures of Oakville are shown in Figures 5 and 7. The age of the Oakville is believed to be Miocene.[6]

UPPER LAGARTO FORMATION

A sand and gravel unit with a thickness of about 15 feet is present in most places at the base of the Upper Lagarto, in which silica-coated limestone pebbles are common, as are also well rounded pebbles and cobbles of limestone, chert, and igneous rock. Overlying the gravel are green, red, and varicolored sandy clays. The clays are well exposed in a pit directly south of the town of Reynosa, Tamaulipas, Mexico (Fig. 2). The Upper Lagarto overlaps the Oakville and Catahoula. No Lower Lagarto exposures have been noted in this area. The Lower Lagarto is well exposed farther north and northeast of the Rio Grande and Reynosa Plateau region, especially in Live Oak, Bee, Goliad, and DeWitt counties where it overlies the Oakville and underlies the Upper Lagarto (Fig. 1).

The Upper Lagarto is believed to be of Pliocene age on the basis of vertebrate fossils.[7]

LISSIE FORMATION

The Lissie is a terrace deposit of Pleistocene age.[8] It has an approximate thickness of 15 feet and extends from the escarpment east of Rio Grande City, southeastward into Hidalgo County (Figs. 2 and 4). The formation is composed of cross-bedded deposits of sand and gravel in which are local irregular pockets of clay. Much of the material in the Lissie was derived from erosion of the Upper Lagarto.

[5] *Ibid.*, pp. 454–57.

[6] *Ibid.*, p. 458.

[7] *Ibid.*, pp. 457–60.

[8] *Ibid.*, p. 461.

FIG. 4.—Photograph showing contact between Pleistocene gravel (Lissie) and Catahoula formation at La Loma de la Cruz, 3 miles east of Rio Grande City, Starr County, Texas. Photograph by S. Brooks.

FIG. 5.—View looking northward at Oakville exposure overlain by Lissie, Porcion 99, south of railroad and old military road and south of west end of Samfordyce oil field in Starr County. Evidence suggests outcrop is situated on downthrown side of fault located between exposure and field.

The southeastward dip of the Lissie along the Rio Grande approximates 6.25 feet per mile.

LEONA FORMATION

Sand and gravel deposits of Leona age, that form a lower terrace level than the Lissie, are exposed at about the level of the present flood plain of the Rio Grande. The materials composing the Leona are similar to those in the Lissie, from which they are thought to have been derived in large part. Leona sand and gravel are quarried directly south of Samfordyce oil field. The formation is considered to be of Pleistocene age.[9]

BEAUMONT FORMATION

The Beaumont formation lies as a thin mantle in a narrow band on the eroded surface of the Lissie from east of Rio Grande City, Starr County, eastward into Hidalgo County where it covers a wider area (Fig. 2). The Beaumont, in Starr and western Hidalgo counties, is sandy, but farther east it is composed of reddish brown clay and some sand beds, and greatly resembles the Beaumont farther north in the Corpus Christi area. The formation is considered to be of Pleistocene age.

REYNOSA CALICHE

The Reynosa caliche is a secondary deposit of calcium carbonate which, in this area, is principally present on the Upper Lagarto and Lissie formations. In general, it is found in its indurated state on all formations older than Beaumont, but as the Oakville and much of the Catahoula in the area are exposed only by drainage beneath overlying Lissie or Upper Lagarto, very little hard caliche is found on them. The major part of the caliche is considered to be of Beaumont age, or perhaps somewhat older.[10]

GEOLOGIC HISTORY

After the Catahoula, Oakville, and Lower Lagarto were deposited, this region was uplifted and eroded. The Upper Lagarto was deposited upon the bevelled edge of these formations. Some slight relief is present on the eroded surface of the older formations for in places the basal sand and gravel unit of the Upper Lagarto is missing and the overlying clay rests directly on the older surface.

After the deposition of the Upper Lagarto there was some regional

[9] *Ibid.*, p. 480.

[10] *Ibid.*, pp. 464–76.

FIG. 6.—View from Lissie-capped Oakville bluff of Figure 5 northeast toward Samfordyce oil field at early stage of development.

FIG. 7.—Oakville sandstone and sandy clay overlain by Lissie gravel in road cut at Samfordyce oil field, Hidalgo County, Texas.

uplift and local doming and faulting which can be noted at various places from the Rio Grande northward, as at Barbacoas in Starr County, Bruni in Webb County, and Pettus and West Tuleta in Bee County. With regional uplift the ancient Rio Grande cut its channel through the Upper Lagarto, into the underlying Oakville and Catahoula, and laid down the Lissie terrace deposit of sand and gravel, much of which probably was derived from the erosion of the Upper Lagarto (Figs. 2 and 3).

Following Lissie deposition the region was again elevated and the Pleistocene Rio Grande cut its channel to approximately its present depth and laid down the Leona deposits of sand and gravel. Following Leona deposition there was a lowering of the land with respect to the sea of approximately 50 feet in this area, and the Beaumont was deposited on the Lissie and around the down-dip edge of the Upper Lagarto. As no hard beds of caliche are noted on the Beaumont, and as caliche is well developed on the Leona, Lissie, and Upper Lagarto, it is quite probable that most of the caliche is of Beaumont age or older. Following Beaumont deposition there was elevation of the area again with respect to the sea, and the Recent cycle of erosion and deposition was initiated.

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CUNNINGHAM FIELD, KINGMAN AND PRATT COUNTIES, KANSAS[1]

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Tulsa, Oklahoma, and Wichita, Kansas

ABSTRACT

The discovery well, drilled in the NE. cor. of Sec. 30, T. 27 S., R 10 W., to test a core-drill structure, found production at 3,360–3,468 feet in the Pennsylvanian Lansing limestone—"Oswald pay"—of western Kansas. Gradual development has resulted in 33 Lansing wells, one Ordovician gas well, one Permian gas well, and two Ordovician dry holes.

The Lansing pay horizons are numerous and variable thin porous streaks, many oölitic, in the upper 110 feet of that limestone formation. The Ordovician gas horizons are the cherty Viola dolomitic limestone, the sands of the upper Simpson and the "Siliceous lime." Oil is present in the "Siliceous lime" below the gas.

The structure had its beginning in post-Mississippian and pre-Marmaton deformation, and its growth continued at intervals in Pennsylvanian and Permian time. It shows increasing steepness and westward shifting with depth.

Production data and production practices are discussed.

I. INTRODUCTION

The development of oil production from the Pennsylvanian limestones of western Kansas began late in 1923 with the discovery of the Fairport field in Russell County.[3] The discovery of Fairport led to considerable prospecting, most of which was confined to the broad, flat Central Kansas uplift,[4] but the results were not very encouraging previous to 1928. During 1928, new discoveries were made in Rooks, Russell, McPherson, and Sedgwick counties, and since that time oil and gas have been produced from the Pennsylvanian, Mississippian, Siluro-Devonian, and Ordovician rocks, and in a few instances from Cambrian and pre-Cambrian rocks where they are in contact locally with overlying Pennsylvanian formations. However, of the oil pools discovered to date, which are productive from the Pennsylvanian limestones, the Fairport field appears to be the greatest in areal extent and the most prolific. The Cunningham field is the next in order of importance.

[1] Read before the Association at Tulsa, March 21, 1936. Manuscript received, February 6, 1937.

[2] Skelly Oil Company.

[3] Thos. H. Allan and M. M. Valerius, "Fairport Oil Field, Russell County, Kansas," *Structures of Typical American Oil Fields*, Vol. I (Amer. Assoc. Petrol. Geol., 1929), p. 35.

[4] Edward A. Koester, "Geology of Central Kansas Uplift," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 10 (October, 1935), pp. 1405–26.

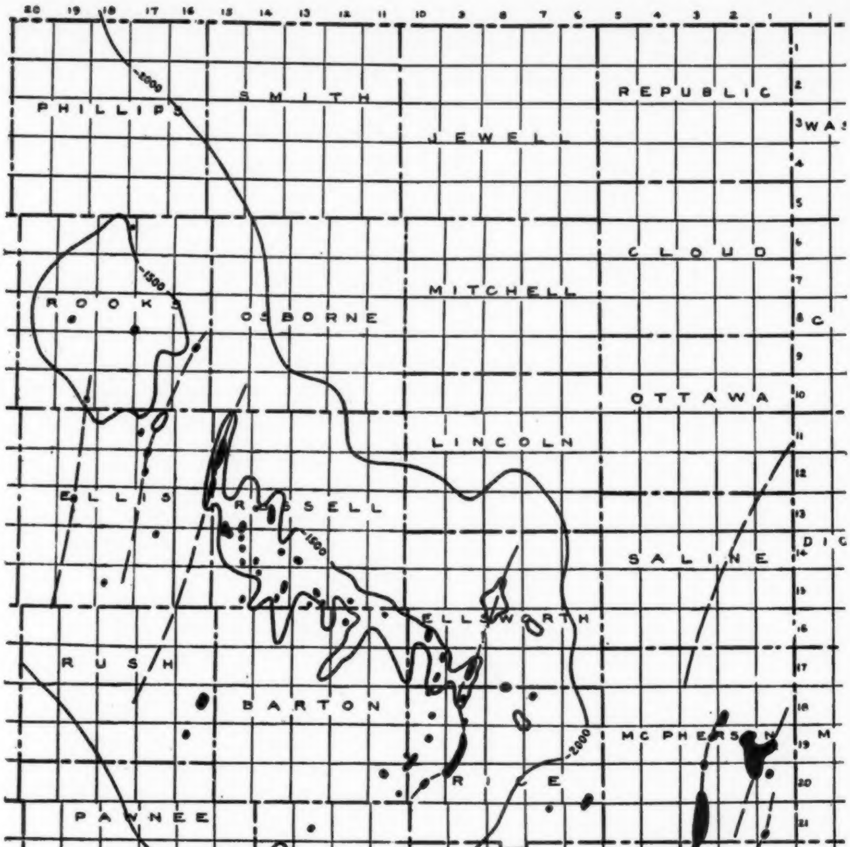

FIG. 1.—Map showing location of Cunningham pool.

II. Relative Location and Accessibility

The accompanying map (Fig. 1) shows the geographic location of the Cunningham field and its relation to the other fields in the general area. The field is 60 miles west of Wichita and 2 miles north of the small town of Cunningham. Production at present is confined to Secs. 19, 20, 29, and 30, T. 27 S., R. 10 W., Kingman County, and Sec. 25, T. 27 S., R. 11 W., Pratt County.

Transportation facilities are adequate. A branch of the A. T. & S. F. Railroad running west from Wichita passes through the town of Cunningham. The paved highway, U. S. 54, passes through Cunningham.

III. History of Early Development

During 1929 a block of several thousand acres was taken by the Skelly Oil Company on incomplete information obtained from core drilling then in progress. Subsequently, considerable additional core drilling was done to complete the local structural picture.

The discovery well, the Skelly Oil Company's F. C. Miles No. 1, NE., NE., NE. of Sec. 30, T. 27 S., R. 10 W., a cable-tool test, was commenced August 28, 1930, was drilled to a total depth of 3,505 feet with an 8-inch hole, where a showing of water was encountered, was successfully plugged back to 3,468 feet, and was completed February 18, 1931. The initial production was 216 barrels of oil and $1\frac{3}{4}$ million cubic feet of gas in 12 hours flowing from the Lansing limestone, the top of which was encountered at 3,360 feet. This was the only well completed during 1931.

During 1932, 4 wells were completed. Three of these were offsets to the discovery. The fourth, Leisman No. 1, cen. of the SE., SW. of Sec. 20, was drilled to the Ordovician where it encountered large volumes of gas in the "Viola limestone," the Simpson sand, and in the top of the "Siliceous lime." After considerable difficulty in drilling with cable tools through these horizons, the test was drilled 100 feet into the "Siliceous lime," the hole was unloaded, and the well began to flow oil of 36° gravity at the rate of 40 barrels per hour. However, after flowing a few hours, water began to show, so the well was plugged back 20 feet, shutting off both the oil and water. It was shut in as an Ordovician gas well. The well was completed as a Lansing oil well, the upper part of that formation having been bradenheaded before the Ordovician formations were tested.

During 1933, 8 more wells were completed in the Lansing limestone. During 1934, 10 additional Lansing limestone wells were completed and 2 tests low on structure were drilled into the Ordovician, plugged,

and abandoned. During 1935, 12 Lansing limestone wells were completed, as well as one shallow gas well with a total depth of 2,150 feet in the Permian. As of February 1, 1936, one additional Lansing oil well was completed.

During the 5 years since discovery, 38 operations have resulted in 35 Lansing oil wells, one of which is an Ordovician gas well also, 2 dry holes to the Ordovician, and one Permian gas well.

IV. Geology

SURFACE STRATIGRAPHY

The productive area of the pool lies in the relatively flat alluvial-filled valley of the Ninnescah River and farther north along the rolling hills which rise gradually 80–100 feet above the valley floor. These hills are composed chiefly of sands and small gravel of the Tertiary. No stratified rocks are exposed.

SUBSURFACE STRATIGRAPHY

The underground sequence of beds is described in the order of penetration by the drill, from top to bottom. The columnar section (Fig. 2) is composite, being derived mainly from microscopic examination by John M. Ware of cable-tool cuttings of the discovery well, F. C. Miles No. 1, NE., NE., NE. of Sec. 30, and Leisman No. 1, cen. of the SE., SW. of Sec. 20, which penetrated 100 feet into the "Siliceous lime." Other information gained from the examination of numerous cores of the Lansing formation has been added. The depth to, and thickness of, the formations of the Permian and Pennyslvanian are those of the discovery well. There is a variation of 220 feet in the thickness of the Mississippian section, depending on the structural position, so that depths to lower formations may be somewhat in error.

TERTIARY

During late Tertiary time, a broad, relatively thin apron of alluvial debris was spread eastward from the Rocky Mountains, overlapping progressively older formations of western Kansas well down into the Permian. This deposit has been dissected by subsequent drainage into large remnants. The Cunningham pool is located near the eastern margin of these Tertiary deposits, which are composed principally of poorly consolidated sands interstratified with small pebbles of quartz, chert, and various rocks, most of which are of igneous origin. The thickness of the formation varies from a few feet to approximately 100 feet, depending on the local topography.

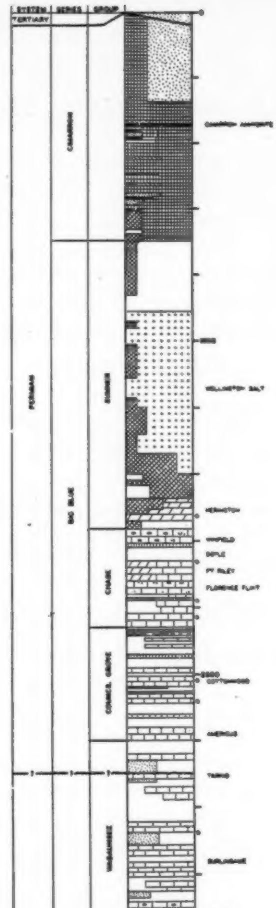

FIG. 2.—Composite stratigraphic section of Cunningham pool.

PERMIAN

The Permian has a thickness of approximately 2,225 feet, if the Permo-Pennsylvanian contact is placed at the top of the Tarkio limestone of the upper Wabaunsee group.[5] The upper Red-bed section, the Cimarron series, is 675 feet thick and consists of 240 feet of fine red sandstones above and 435 feet of red sandy shales and silts below, with minor amounts of variegated red, green, and gray sandy shale and some gypsum, anhydrite, and dolomite. One thin anhydrite member at a depth of 350 feet is an excellent core-drill and subsurface marker and can be traced for many miles west and northwest.

The lower non-red Permian, the Big Blue series, is 1,500 feet thick. The upper 850 feet of this section, the Sumner group, is composed of 200 feet of blue shale, approximately 450 feet of salt, anhydrite, and gray shale, and 110 feet of gray shale and anhydrite of the Wellington formation. Below this group is 90 feet of section, the upper 30 feet of which is anhydrite with some dolomite, and the next 40 feet is dolomite which is equivalent to the Herington limestone farther east and is a good core-drill marker for holes below the salt. The lower 20 feet is the Enterprise dolomitic shale, which is the basal member of the Sumner group. The lower 750 feet of the non-red Permian is composed of numerous limestones and shales. The limestones in the upper 150 feet of this section are dolomitic, and in the lower part these are two or three thin locally oölitic horizons. The Florence flint near the middle of the Chase group, a cherty limestone at 1,720–1,760 feet, is easily identifiable because of its highly fossiliferous chert content. The shales are gray for the most part, but there are a few red shales, such as those at 1,610–1,625 feet in the Doyle shale, and at 1,865–1,875 and 1,940–1,950 feet in the Garrison formation of the Council Grove group, which are rather prominent and persistent in a considerable area. The aforementioned markers are useful for shallow correlations.

PENNSYLVANIAN

The Pennsylvanian sediments have a thickness of 1,530 feet, and in western Kansas the divisions as used by Koester[6] are the Virgil series above, and the Missouri and Des Moines series below. Ockerman[7] has recently made a detailed classification of these rocks exposed in northeastern Kansas.

[5] Edward A. Koester, *op. cit.*, p. 1411.

[6] Edward A. Koester, *op. cit.*, p. 1411.

[7] John W. Ockerman, "Subsurface Studies in Northeastern Kansas," *Univ. of Kansas Bull. 20*, Vol. 36, No. 9 (1935), p. 14.

The Virgil series, composed of the lower Wabaunsee and the Shawnee and Douglas groups, is 1,060 feet thick. This series is separated from the Permian above and from the Missouri series below by a widespread but inconspicuous unconformity. The base of the Wabaunsee is placed at 2,840 feet, at the base of the Severy shale. The Shawnee group extends from the top of the Topeka limestone at 2,840 to the base of the Oread limestone at 3,220 feet. The Douglas group extends from the top of the Lawrence shale at 3,220 to the top of the Stanton limestone at 3,360 feet, and probably includes the Pedee group of Moore and Condra, if that group extends as far south and west as the area under discussion.

The Wabaunsee and Shawnee groups are made up of interstratified gray shale and limestone members. The shales at two or three horizons are somewhat arenaceous. In the Shawnee group, limestones comprise the greater part of the section. The Douglas group is dominantly gray shale. A water sand, which is very erratic in distribution and varies from a very thin layer to 100 feet in thickness, is present in many places near the middle of this group. The lower 12–15 feet of the Douglas group is made up of 10–12 feet of very hard, siliceous, nodular beds of limestone, generally 1–2 inches thick, which are interbedded with a slightly less amount of hard, silicified, dark gray shale. Separating this "shelly zone" from the massive crystalline fossiliferous Stanton limestone below, is a bed of soft, greasy, black shale, generally 1–2 feet thick. Some wells drilled down on the flanks of the structure have cored as much as 10 feet of red or red and green shale section between the "shelly zone" and the top of the coarsely crystalline fossiliferous Stanton limestone.

The Missouri series present at 3,360–3,710 feet is made up of the Lansing and Kansas City groups, and is separated from the Virgil series above by a slight angular unconformity.

The Lansing and Kansas City groups are a lithologic unit predominantly of gray limestones of varying crystallinity with several thin but recognizable cherty and oölitic horizons. Interbedded with these limestones, but comprising only a very minor amount of the total section, are dark gray shales varying in thickness from a thin seam along the bedding plane to beds ranging from 5 to 10 feet in thickness, a few of which are present in the middle and lower part of the Lansing and Kansas City groups.

The two groups have a combined thickness of 350 feet, which probably can be divided equally between them as there is no distinct line separating the groups.

Koester[8] has designated these groups as the Oswald limestone, a term in common use in Kansas since the discovery of the Fairport field, Russell County, and has given an excellent general description of their character and extent in western Kansas.

The Des Moines series is represented by the Marmaton group only. Rocks of Cherokee age are not present. The Marmaton group is 120 feet thick. A few thin, dense, silty, noticeably red-gray limestones are interbedded with the shales, which are predominantly gray in the upper part of the group. Red rocks and red, green, and gray variegated shales become increasingly prominent as the unconformable contact with the Mississippian is approached. This unconformity is widespread and is decidedly angular locally.

MISSISSIPPIAN

Rocks of Mississippian age have a thickness of 300 feet in deep tests drilled off structure. This is approximately the normal thickness for the general area. Higher on structure, post-Morrow and pre-Marmaton erosion has removed the greater part of this section, for example in Leisman No. 1, cen. of the SE., SW. of Sec. 20, where only the lower 80 feet remains.

In South Rouse No. 1, cen. of the north line of the SE. ¼ of Sec. 20, the rocks at 3,980–4,085 feet are classified as the "Mississippi lime" section. The upper few feet of this section are composed of white and gray chert, which shows evidence of weathering and redeposition with small amounts of variegated shale and a few sand grains. This deposit, derived from the underlying Mississippian cherts, represents the basal Pennsylvanian deposit of the area, and, in a strict sense, is Marmaton in age and could be classed as a part of the "Sooy conglomerate" of Edson.[9] The next 60 feet is predominantly light-colored chert with small amounts of dolomitic limestone which shows indication of secondary silicification and dolomitization. The term "Mississippi chat" is in common usage for this section. The next 30 feet is a cherty white to tan crystalline limestone, which probably is the equivalent of the St. Joe member of the Boone.

Beneath the "Mississippi lime" section is 190 feet of dark gray, spore-bearing Kinderhook shale. The top 125 feet of this shale is medium-gray and contains very few spores. Next in order is 25 feet of silty, thin-bedded, gray spore-bearing dolomite. The dolomitic phase of the Kinderhook is frequently recorded as "lime" in a driller's

[8] Edward A. Koester, *op. cit.*, p. 1412.

[9] F. C. Edson, "The Sooy Conglomerate of Kansas," *Tulsa Geol. Soc. Digest* (1934), pp. 30–32.

log. That part of the shale section underlying the silty dolomite contains very abundant spores in the bottom part and is calcareous and black in color. It has been correlated with the Chattanooga shales by some who have worked in the area.

ORDOVICIAN

Unconformably underlying the rocks of Mississippian age, are Ordovician rocks, 290 feet of which were tested by Leisman No. 1, cen. of the SE., SW. of Sec. 20, and the depths given in connection with the following description of these formations are depths in that well.

"Viola limestone" is a term commonly used when referring to a series of cherty dolomites, dolomitic limestones, and limestones present at 3,922–4,003 feet. The upper 60 feet of this group is finely crystalline, very cherty near the top, but contains considerably less chert in the lower part, and probably is pre-Fernvale Viola in age as compared with the Oklahoma section. The lower 20 feet is non-cherty, coarsely crystalline white limestone which is traceable over a broad area in western Kansas. This lower limestone has been placed in the Simpson by some writers.[10]

The Simpson formation, 90 feet thick, underlies the Viola, and probably is the equivalent of the upper Simpson of Oklahoma. The upper 40 feet of this formation consists of interbedded medium-to-fine-grained sands and sandy green shales, the sands predominating especially near the top. The lower part of the formation is fossiliferous green shale with a minor amount of sandy green shale, but contains very little or no sand.

The "Siliceous lime,"[11] which underlies the Simpson unconformably, was encountered in Leisman No. 1 at 4,094 feet and penetrated 101 feet to the total depth. Frequently it is classified as the Arbuckle limestone of the Oklahoma section, but Koester[12] has presented evidence which indicates that correlations with the Ordovician section of the Ozark region are more specific.

The "Siliceous lime" penetrated is a medium-crystalline, dolomitic, siliceous limestone containing several cherty horizons, a few thin sand streaks included in the dolomite, and in the last few feet a small amount of pale green shale with a greasy luster, which probably is in thin seams or beds only a few inches thick.

[10] T. C. Hiestand, "Voshell Field, McPherson County, Kansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, No. 2 (February, 1933), p. 74.

[11] F. L. Aurin, G. C. Clark, and Earl A. Trager, "Notes on the Subsurface Pre-Pennsylvanian Stratigraphy of the Northern Mid-Continent Oil Fields," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 5, No. 2 (February, 1921), pp. 117–53.

[12] Edward A. Koester, *op. cit.*, p. 1417.

V. Oil and Gas Horizons

The one cable-tool test drilled through the Permian and Upper Pennsylvanian found small amounts of gas in several horizons, and oil and gas in the Lansing series. A cable-tool test of the lower formations showed the presence of gas in the Viola and Simpson formations, and gas and oil in the "Siliceous lime."

The Permian has several horizons which contain gas. A small showing was encountered at 1,525–1,530 feet in the Herington dolomite; 1½ million cubic feet at 1,635–1,650 feet in the Fort Riley dolomite; an estimated ¼ million at 1,780 feet in limestone of the Matfield shale section; an estimated ¼ million at 1,988–1,990 feet in limestone just above the Cottonwood limestone; 6 million gauged at 2,005–2,025 feet in the Cottonwood limestone; 4 million gauged at 2,133–2,142 feet from the Glen Rock limestone; and ¾ million estimated at 2,160–2,162 feet in the Americus limestone. Recently a gas well in the cen. of the NW., NW. of Sec. 29 produced 6½ million cubic feet from 1,993–2,150 feet in the Cottonwood and Glen Rock limestones of the Council Grove group.

In the Upper Pennsylvanian, an estimated ¼ million cubic feet of gas was encountered at 2,475 feet in a sandy shale of the Wabaunsee group, and another ¼ million at 3,030–3,035 feet in a limestone in the middle of the Shawnee group.

The oil horizon which is being developed is the Lansing limestone group, commonly referred to in western Kansas as the "Oswald lime," was penetrated 156 feet in the discovery well, F. C. Miles No. 1. The first zone, the top 28 feet of the Lansing, is gray, heavy-bedded, coarsely crystalline, fossiliferous limestone which contains a small amount of light-colored chert in the bottom 3 feet. In a few of the wells there is a thin coquina bed, approximately 5 feet from the top. Cores show that in many places the beds are separated by thin black shale partings. Generally a showing of gas and oil is found in the top few feet of the zone. Oil-saturated streaks ranging from an inch to several inches in thickness occur in the porous, coarsely crystalline phases, in the oölitic phase, and in many places in the limestone adjacent to a thin black shale parting.

This zone is underlain by the main "pay" of the field, the 30-foot "pay," which is an oölitic bed generally 4 or 5 feet thick. This oölitic bed is present and productive in most of the wells. In some of the better wells, many of the individual oölites apparently have been removed by solution, leaving what might be termed a "pseudo-oölitic" porosity. Below this main oölitic zone is 28 feet of slightly cherty limestone marked by a dark gray, very cherty bed at the base.

A thin oölitic bed occurs locally near the middle of this zone. A few thin pay streaks are indicated by increases of oil and gas obtained by some wells while drilling this zone, and by the recovery of some saturated cuttings.

Below this zone the next 25 feet of limestone appears to contain more numerous shale partings and gives little indication of containing oil in appreciable amounts. Immediately below this practically barren zone, and 86 feet below the top of the Lansing, is a cherty limestone bed, probably 2 or 3 feet thick, which because of its black chert can be recognized not only in all wells drilled to that horizon in the field, but also in several tests drilled in the surrounding area. Porosity in this horizon is indicated by increases in gas and oil in wells high on the structure and by 3–5 bailers of water per hour in wells structurally lower. Cuttings show a decided fractured condition of the chert, indicating the nature of the porosity. Approximately 25 feet below the black cherty bed, and 110 feet below the top of the Lansing, is a thin oölitic bed, productive of gas in the few wells located on top of the structure which have been drilled to that penetration. At a penetration of 175 feet below the top of the Lansing, a 10-foot bed of oölitic limestone, persistent in the general area, produced $\frac{1}{4}$ million cubic feet of gas in Leisman No. 1, cen. of the SE., SW. of Sec. 20, a well high on structure. The remaining 165 feet of the Lansing-Kansas City section contains two or three locally oölitic beds which generally contain light showings of gas and oil and water. In this part of the section there is considerably more shale, probably in beds a few feet thick. Many of the limestones are dark and finely crystalline to dense. There is very little porosity.

Whether or not there was a common water table for all the Lansing producing horizons is a difficult question to answer. The earliest wells encountered water near a datum of −1,830. Later wells found water at approximately −1,800. It appears very probable that, had the earlier wells found porosity between the −1,800 and the −1,830 datums where water was encountered, the water would have been found slightly below the −1,800 datum. Because of unequal porosity and permeability in the various thin pay streaks, unequal drainage and water encroachment has resulted, and a few of the later wells have produced small amounts of water at various horizons. Probably this erratic water condition will become more noticeable in future developments, but there is no indication that large volumes of water will be produced with the oil from the Lansing horizons.

The one deep test drilled sufficiently high on structure to be productive in the lower horizons is Leisman No. 1, cen. of the SE., SW.

of Sec. 20. The Mississippian "chat," a potentially productive horizon, was removed by erosion. The Viola cherty dolomite was encountered at 3,922 feet, and at 3,925 feet tested 13 million cubic feet of gas. At 3,958, a penetration of 36 feet, another test showed an increase to 26 million with 1,385 pounds rock pressure. The hole was loaded with mud and drilled to 3,995 feet without testing, where $5\frac{3}{16}$-inch casing was set and the gas from the Viola cased off. The Simpson was reached at 4,003 feet. At 4,055 feet a test showed 9 million cubic feet of gas from the 52 feet of sands and sandy shales of the Simpson. The lower part of this formation extending down to 4,094 feet, which is predominantly green shale, probably contained no increase. The $5\frac{3}{16}$-inch casing was lowered to 4,094 feet and cemented on top of the "Siliceous lime." A test at 4,109, a penetration of 15 feet, showed $8\frac{1}{2}$ million cubic feet of gas. The hole was then loaded and drilled to 4,195, a penetration of 101 feet. After unloading, the well began flowing 26 million cubic feet of gas and 40 barrels of oil per hour, but after a few hours flow, some water began to show. The well was shut in immediately, and later plugged back to 4,175 feet. A later test showed 27 million cubic feet of gas, no oil, and no water, indicating that the oil came from the bottom 20 feet of the hole. Later the hole was cemented back to the Viola and the $5\frac{3}{16}$-inch casing shot at that horizon. The well tested 56 million cubic feet of gas from the Viola and was shut in.

Such large volumes of gas from the Viola, Simpson, and "Siliceous lime" horizons were unknown previously in Kansas. The oil found in the "Siliceous lime" below the gas, and oil produced not far distant in the Simpson and Viola, indicate that there is a good probability of producing oil from all three of these formations if tested at the proper structural position.

VI. Structure

The Cunningham dome was found by core drilling. The marker on which the core-drill map (Fig. 3) has been constructed is the Cimarron anhydrite found at a depth of 350–450 feet. This bed has been called the Stone Corall member of the Harper sandstone by George Norton.[13] Several core holes were carried down to the base of the Cimarron red beds at 700–800 feet, and a few critical ones were drilled through the salt series to the base of the Wellington, a depth of approximately 1,500 feet. The amount of closure on the Cimarron anhydrite is 25 feet, but on the lower markers it exceeds 30 feet.

[13] George Norton, paper given before the Kansas Geological Society, April 17, 1935.

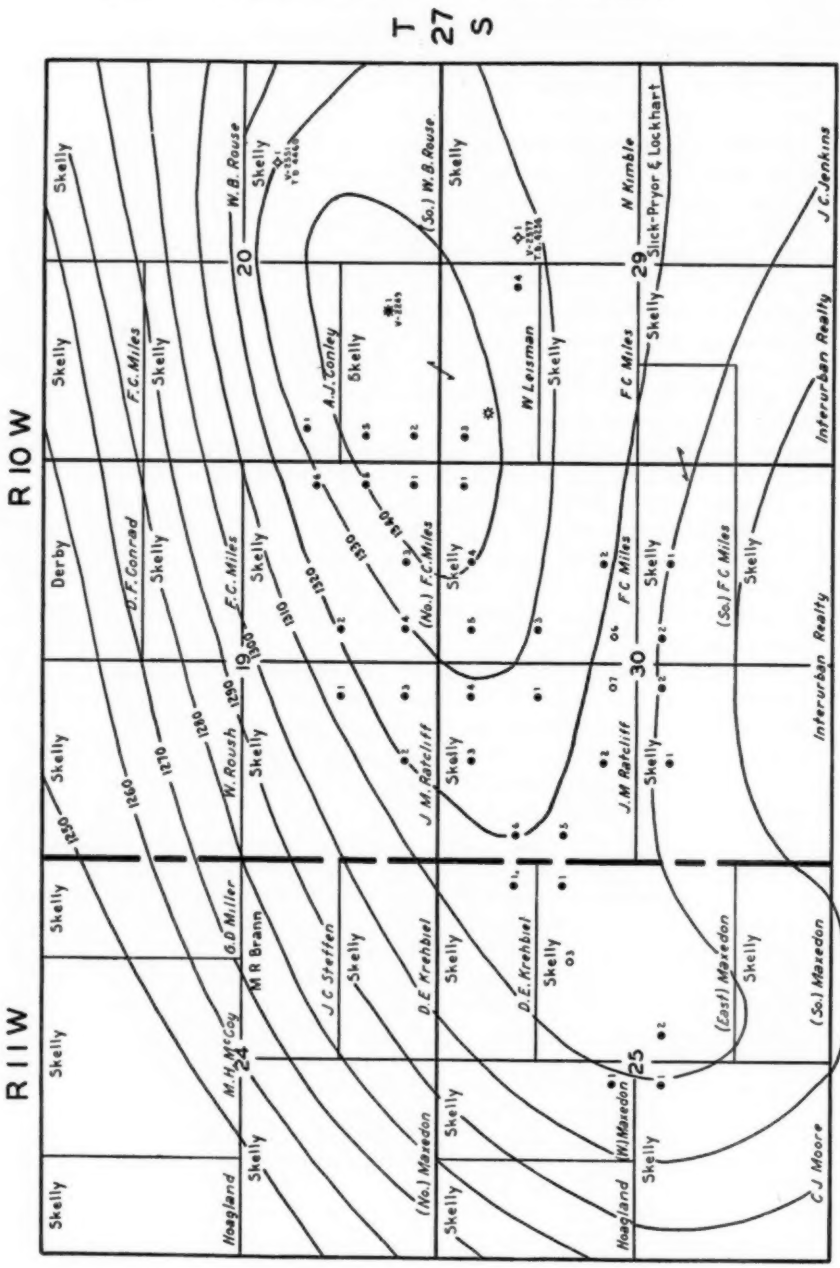

FIG. 3.—Core-drill structure map of Cunningham pool. Datum, Cimarron anhydrite above sea-level. Contour interval, 10 feet. *V*, Viola limestone below sea-level.

Because of the southeastward regional divergence off the Barton arch between the core-drill marker and the Lower Pennsylvanian beds, and especially between the core-drill marker and the formations below the post-Mississippian unconformity, the north and northwest dips are the critical dips and are more important than a few additional feet of closure. The core-drill map shows that these rates of dip are considerably in excess of the post-Permian westward tilting.

The structure on top of the Lansing limestone (Fig. 4) has a striking similarity to the core-drill structure. The axes of the structures are almost superimposed. The highest point of the Lansing structure is possibly 2,000 feet west of the top of the core-drill structure, and steep southeast and northeast dips have developed approximately a half mile farther west than where they were indicated on the core-drill structure. At the present stage of development, insufficient data are available to determine whether the steep north and west core-drill dips will be underlain merely by steeper dips on the Lansing or by steep dips and faulting. There is nothing to indicate the faulting except possibly a suggestion of an adjusted water table in the various pay horizons in the Lansing limestone.

From an analysis of all the faults that may be observed in Mississippian and older rocks in central and western Kansas to date, no such faults have been found to pass upward above the post-Mississippian unconformity, and all of them register as only steep dip in beds above that unconformity. Therefore, it appears unlikely that faulting will be found at Cunningham in beds of Pennsylvanian age even if faulting is present in the older rocks below.

Information on the Ordovician structure is limited to three deep tests: a gas well, cen. of the SE., SW. of Sec. 20; a dry hole, cen. of the north line of the SE. $\frac{1}{4}$ of Sec. 20; and a dry hole, SW., NW., NE. of Sec. 29. The rate of dip on the Viola as shown by these three tests is practically three times that on top of the Lansing. The increase in rate of dip results chiefly from truncation of the Mississippian section, the 100 feet of Mississippian chert and limestone and 120 feet of Kinderhook shale below having been removed by pre-Marmaton erosion. This and the large volume of gas encountered in drilling the upper 273 feet of the Ordovician formations point toward Ordovician structure with considerably more closure than is present in the Pennsylvanian. The high rates of dip shown on the Ordovician suggest the possibility of pre-Marmaton faulting being associated with the structure.

The following discussion of the structural history of the Cunningham structure is based chiefly on the information obtained from

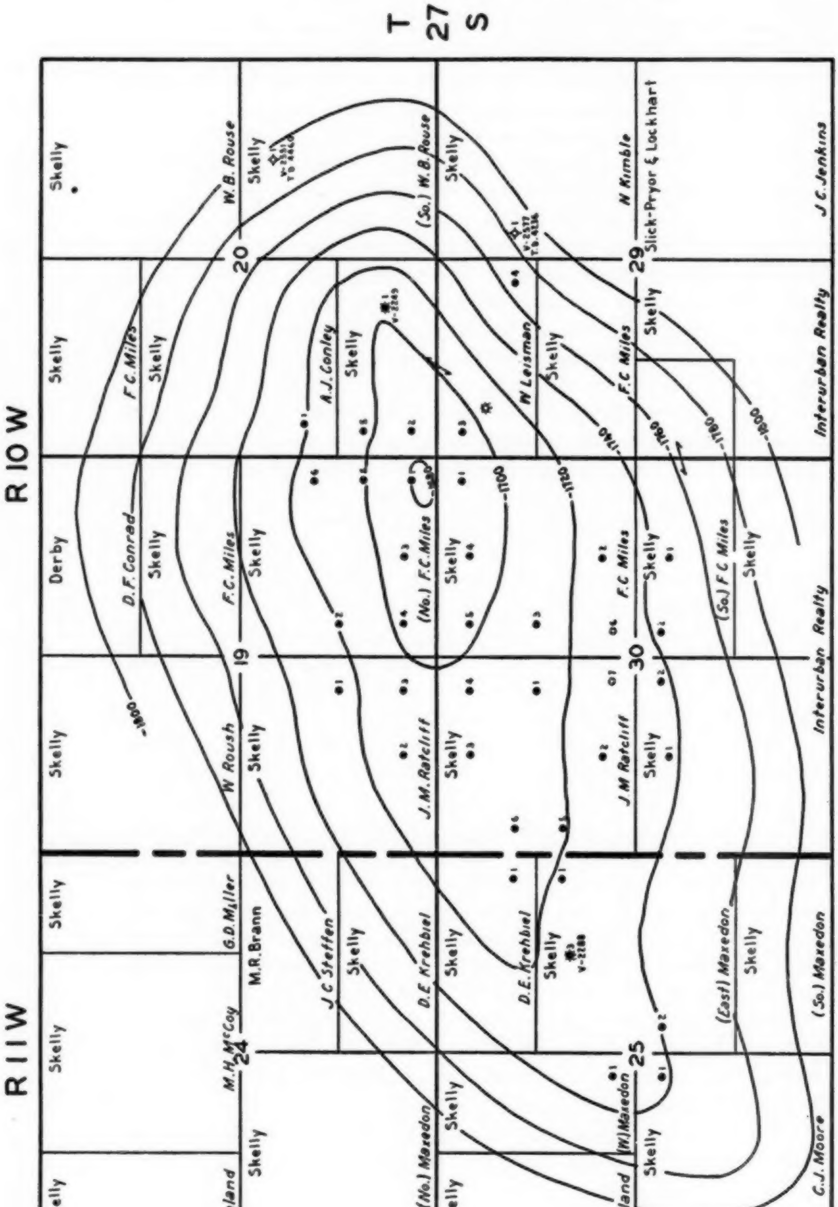

FIG. 4.—Subsurface structure map of Cunningham pool. Datum, top of Lansing limestone below sea-level. Contour interval, 20 feet. *V*, Viola limestone below sea-level.

records of wells in the field and in the near-by area. No serious attempt is made to indicate more than the relation of the local structural events to those of the general area.

No appreciably local structural effect was produced by the widespread deformative movements which resulted in a major unconformity on the top of the "Siliceous lime." The same is true of those movements which produced depositional breaks, probably accompanied by some erosion, at the base of the "Viola lime" and possibly at some horizons within it. The widespread post-Hunton pre-Kinderhook uplift and subsequent erosion removed the Siluro-Devonian rocks if any were present, but left no apparent local structure.

The history of the Cunningham structure as such probably begins with the widespread post-Wapanucka movements—Wichita orogeny. At that time, farther north and west the Central Kansas uplift, which had long been in existence, was broadly elevated and folded along northeast-southwest trends. Farther east, the Nemaha granite ridge was uplifted and faulted, and similar but less intense movements took place along the Voshell trend in McPherson County and other structural trends nearly paralleling them. As the initial uplift of the Cunningham structure doubtless occurred at this time, the logical assumption is that it too had a northeast-southwest trend. The amount of uplift was at least 220 feet. The uplifted area was reduced practically to the level of the surrounding terrane previous to deposition of the earliest Pennsylvanian sediments, the Marmaton shales. These events are indicated by the absence near the top of the structure of the upper 220 feet of the Mississippian section and the presence of a Marmaton section which, though slightly thin regionally, is the same in wells high on structure and near-by low dry holes.

The next period of structural growth was post-Lansing pre-Douglas. This movement is correlated with the warping and gentle folding which produced the post-Oswald unconformity over the Central Kansas uplift. The presence of detrital material above the Lansing in wells on the flanks of the structure suggests removal from near the apex of some of the upper part of the Missouri series. A short interval from the top of the Lansing to the main oölitic "pay" in the high wells is further proof. An interval from Lansing to Oread, 40 feet less than normal, is indicative of the amount of local uplift.

During the time represented by the remainder of the Pennsylvanian and the Permian sediments up to the base of the Cimarron redbeds, there are indications of minor, more or less compensating, structural movements along the axis of the Cunningham structural trend, but no clear-cut evidence of marked structural growth at any

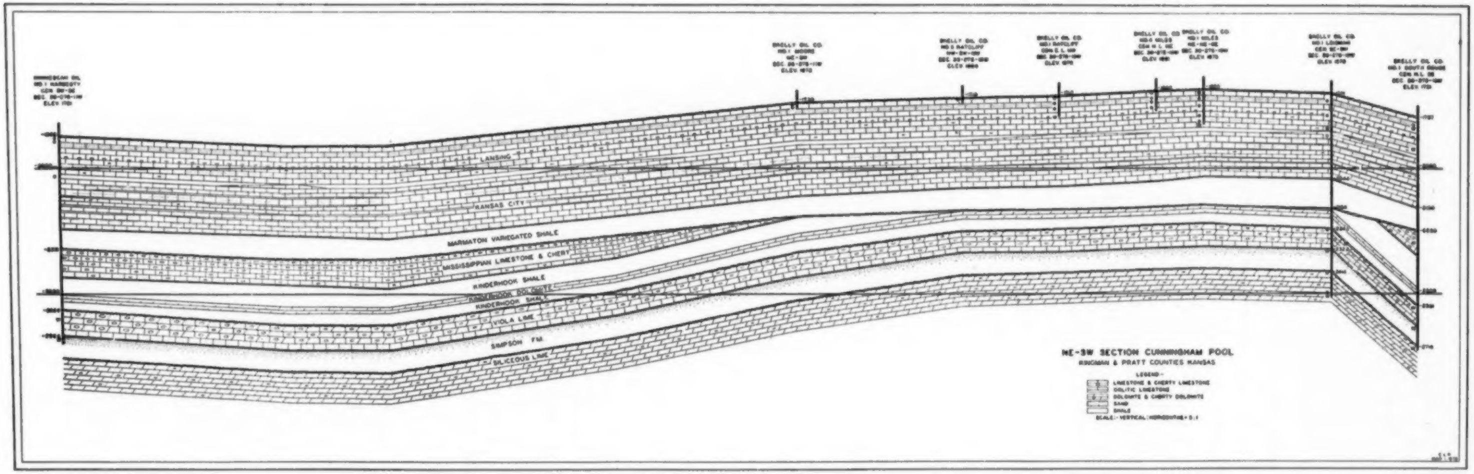

FIG. 5.—Northeast-southwest geologic section through Cunningham pool. Figures in section show feet below sea-level.

one time of the Cunningham structure. However, a gradual growth is indicated by an accumulated shortening of 40 feet in the entire section as compared with the normal section from the base of the Oread to the base of the red-beds. An additional thinning ranging from 10 to 15 feet shown by core drilling exists between the core-drill marker and the base of the red-beds.

The last period of structural growth is placed by inference as post-Cretaceous and is the local effect of that general movement which affected the area farther north and west, reviving older folding along northeast and southwest anticlines. The present core-drill structure is thought to be largely a result of local folding and northwest tilting during that time.

VII. Development and Production Practice[14]

DEVELOPMENT

Following the discovery of the pool early in January, 1931, an orderly development campaign was begun. All wells to date have been drilled by the Skelly Oil Company.

Of the 36 producers, 33 were completed as either oil wells or combination oil and gas wells from the Lansing series alone. The average depth to the top of the Lansing is 3,400 feet. The average penetration of the series drilled is 68 feet, the minimum 40 feet, and the maximum 129 feet.

The discovery well, F. C. Miles No. 1, NE. cor of Sec. 30, T. 27 S., R. 10 W., drilled by cable tools, was completed so as to include the gas from two shallow horizons, at 2,002–2,142 feet, in a bradenhead between the 10- and 12½-inch casing, as well as gas and oil from the Lansing horizon through the 8-inch casing cemented at 3,375 feet on top of that formation.

The first Ordovician test, Wendel Leisman No. 1, cen. of the SE., SW. of Sec. 20, T. 27 S., R. 10 W., was drilled to a total depth of 4,195 feet in the "Siliceous lime." After finding large volumes of gas in the Viola, Simpson, and upper part of the "Siliceous lime" section, and oil and water below the gas in the "Siliceous lime," it was plugged back to the Viola and completed as a gas well in that horizon, producing through 6-inch casing cemented at 3,922 feet on top of that formation. This well also produces gas and oil from the Lansing series through a bradenhead between the 10-inch casing

[14] The data for this phase of the report have been furnished by Howard S. Bryant, who has been in close touch with field operations since the beginning of the development.

cemented on top of that formation at 3,378 feet and the 8-inch casing set below the oil zone at 3,485 feet.

The remaining producer is a shallow gas well, Leisman No. 6, cen. of the NW., NW. of Sec. 29, T. 27 S., R. 10 W., with a total depth of 2,150 feet.

The two dry holes drilled to date, Kimble No. 1, SW., NW., NE. of Sec. 29, and South Rouse No. 1, cen. of the north line of the SE. ¼ of Sec. 20, found the top of the Lansing 115 feet lower than the crest of the structure. Both of these dry holes were drilled on the east side of the field, defining it in that direction. None of the producing wells drilled is yet exhausted. At present there is one drilling well, and three required offsets to be drilled.

Without having the structure defined to date on its north and west sides, it is necessary to estimate the probable total productive area from the available structural information at 1,900 acres, slightly more than half of which has been developed.

DRILLING PRACTICE

The discovery well was drilled by cable tools. Subsequent drilling has been done by heavy steam rotary-type equipment. Standard 122-foot derricks are used and, where the terrane permits, are skidded to the next location while standing. All drilling is done by contract.

The average drilling time to the top of the Lansing ranges from 17 to 19 days counting the time from starting under the surface pipe to the running and cementing of 7-inch pipe on top of the Lansing, and including the time necessary for taking one or more cores to accurately determine the top of that formation.

The weight carried on the drill pipe at a depth of 2,000 feet and deeper averages 25 per cent of the weight of the drill pipe and blocks, which amounts to approximately 5,000 pounds at 2,000 feet and 7,000–8,000 pounds at 3,500 feet. There is very little difficulty in the drilling of straight holes, the average deviation from vertical being not more than 1°–1½°.

The rotary holes make very little natural rotary mud. They are drilled to a point just above the porous limestone series, encountered at 2,000–2,150 feet, with water only. Then the drilling fluid is conditioned with cotton-seed hulls, aquagel, or Wewoka mud. This porous series, as well as the soft sand and porous limestone series at 2,600–2,650 feet, causes heavy loss of drilling fluid if the mud is not thickened sufficiently. A third zone approximately 90 feet above the top of the Lansing generally causes a loss of 30 per cent of the returns for a short time even when drilled through with well thickened

mud. Ordinarily, 2 tons of cotton sand hulls and 4 or 5 tons of aquagel or Wewoka mud are added to the drilling fluid on each well drilled.

CASING AND CEMENTING PROBLEMS

The first casing run is 12½-inch. It is set at an average depth of 285 feet and cemented under pressure all the way to the surface. As all holes encounter Permian red-beds above this depth, cementing to the surface is effective both in sealing off the shallow artesian salt water and in protecting the fresh-water zones which are in the Quaternary and Tertiary sands and gravels above the Permian.

The next casing, usually the only additional string, is A. P. I. 7-inch O. D., grade C, seamless, 24-pound, which is set in the top few feet of the Lansing series and cemented with 500–550 sacks of cement under pressure by the single stage 2-plug method.

In drilling the original cable-tool hole, F. C. Miles No. 1, NE. cor. of Sec. 30, ten Permian and Pennsylvanian gas zones were encountered at intervals from 1,525 feet to 3,165 feet above the Lansing series. In all the subsequent drilling by rotary tools, it has been considered practicable to seal off and protect all these gas zones from various water-producing horizons found between them by placing cement back of the 7-inch oil string so as to cement solidly from the casing shoe on up above 1,525 feet.

COMPLETION PRACTICE

The customary practice is to standardize while waiting for the cement to cure. This requires 4 or 5 days. Then the hole is bailed clean of rotary mud, the cement is drilled, the cement job tested for water shut-off, and the producing zone in the Lansing limestone is drilled by cable tools.

A skirt of corrugated sheet iron is used to inclose the derrick entirely as high as the fourble boards before drilling into the pay zone, in order to protect the ground, surrounding crops, and the Ninnescah River from damage. After the desired penetration of the pay horizon has been drilled, the wells are given a 1- or 2-day production test, either by flowing naturally or by flowing and swabbing, and an accurate gauge of both oil and gas is kept.

ACID TREATMENT

Since the advent of acidization, wells are treated with acid immediately after their short natural production test and before completion. In all acid treatments previous to 5 months ago, 1,000 gallons of acid per treatment was used, with only the pressure obtained be-

tween the column of acid in the tubing and the oil and gas column in the casing. Since that time, larger volumes of acid, ranging from 2,000 to 5,000 gallons per treatment, have been run in under pressure, and a shorter time given for the reaction.

The effect of the first acid treatment on the initial production of the Lansing limestone wells has been an average increase in the initial oil production of 320 per cent, except in a very few cases. Usually the gas volume is increased also. In some wells where the oil volume has shown an unusually large increase, the gas volume has decreased, probably because of the oil column holding increased back pressure on the bottom of the hole.

Treating by acid the second time has shown no measurable increase in the daily oil production, judging from accurate 15-day production tests made on several wells immediately before and after such second treatment. This failure to register a production increase seems to be general for all parts of the Cunningham pool, even after experimenting with several methods of acid treatment.

Just what effect acid treatment will have on the total ultimate oil and gas production of the pool can not be foretold at this date. However, it has been demonstrated that initial production as high as 285 barrels per day has resulted from acid treatment of practically dry holes, which in pre-acid days doubtless would have been abandoned as non-commercial wells. The ultimate productivity of such wells can not be estimated satisfactorily because of their recent completion.

PRODUCTION STATUS

The 35 wells producing from the Lansing series completed to date show an average initial production, after acidization, of 392 barrels per well per day, with a minimum of 50 barrels and a maximum of 1,185 barrels. The average initial gas volume with the oil is 1,675,000 cubic feet per well, the maximum 9,500,000, and the minimum 50,000.

The pool has not been produced in its capacity, having been produced since inception under proration. The daily average production has been kept, except for short periods of time, well below the allowable figure set by the proration umpire.

On January 1, 1936, the field had produced a total of 1,009,874 barrels of oil from the Lansing series. The largest amount produced in a single month was 48,743 barrels during May, 1934, an average daily production of 1,572 barrels. On March 1, 1936, the pool was being produced at the rate of 900 barrels per day.

BOTTOM-HOLE PRESSURES AND TEMPERATURES

Bottom-hole pressures and temperatures have been taken since August 1, 1933, at six different times. Readings are taken by pressure bomb run on a Halliburton steel line inside the tubing, the bomb being run near the bottom of the tubing, which is set at or below the deepest oil-producing zone. Because of gas-market requirements, bottom-hole pressures can not be taken all at once with the field completely shut in. In practice, pressure readings are taken on one group of wells at a time, the group having been shut in for 48 hours at both the casing and tubing head, and all offset wells shut in in a similar manner for 24 hours.

On August 1, 1933, the date of first readings, the average bottom-hole pressure on five of the six wells then completed was 1,110 pounds per square inch. The last reading, taken on 28 wells from November 5 to 11, 1935, showed an average bottom-hole pressure of 492 pounds, a decline of 612 pounds which is $55\frac{1}{2}$ per cent of the original field pressure.

On January 7, 1936, two months after these last pressure readings were taken, a repressuring program was started to check any further decline of bottom-hole pressures in the field. This program has been in operation only a short time and no additional bottom-hole pressures have been taken to date.

Bottom-hole temperatures taken at the same time as the bottom-hole pressures ranged from 120° to 114°. The average was 118.5° and the average depth of the readings was 3,422 feet. It has not been found possible to correlate the small differences in temperature that exist with the structural position of the wells, their dates of completion, the amounts of water or oil being produced, or any other data.

The variation in average bottom-hole temperature of the field has been not more than $\frac{1}{2}$° in the $2\frac{1}{2}$ years the readings have been taken. The fact that bottom-hole temperatures have not shown appreciable increase with water encroachment may be attributed to the relatively small amounts of water produced with the oil to date.

PRODUCTS

The production may be considered as coming from three zones: the Permian gas zone, the Lansing oil and gas zone, and the Ordovician gas zone.

The Permian gas zone is productive of dry gas only. Analysis of gas from two of these horizons found in F. C. Miles No. 1, NE. cor. of Sec. 30, T. 27 S., R. 10 W., is given in Table I.

TABLE I

	Gas Zone, 2,005–2,020 Feet	*Gas Zone, 2,133–2,142 Feet*
Amount of gas	6,000,000 cubic feet per day	9,200,000 cubic feet per day
Rock pressure (S.I.)	675 pounds per square inch	740 pounds per square inch
Oxygen	0.1%	0.3%
Carbon dioxide	0.2	0.1
Ethane	12.0	12.2
Methane	71.8	72.8
Residue	15.9	14.6
Total	100.0%	100.0%
Heat value	937 B.T.U.	
Gross value	30″ at 60°F.	30″ at 60°F.
Sample taken	October 14, 1930	November 8, 1930

The Lansing oil and gas zone produces oil ranging in gravity from 31° to 36° A.P.I., which has a pour point below zero, contains ½ of 1 per cent sulphur, and is dark brown in color. On a straight distillation test, it separates into 35 per cent gasoline, 10 per cent kerosene, 25 per cent gas oil, and 30 per cent bottoms and distillation loss. The gasoline is slightly sour. The crude itself is fairly free from wax.

Oil shipment in tank cars was begun November 14, 1931. Early in March, 1934, the Skelly Oil Company completed a 52-mile extension of its main pipe-line system from Burrton, Kansas, to the Cunningham pool, and since that time has run the oil directly to its refinery at Eldorado, Kansas.

A combination gasoline plant, using a straight oil absorption process, and a gas boosting station was put in operation by the Skelly Oil Company on April 24, 1934. This plant operates under field pressure, takes the gas being produced with the oil from the Lansing series, removes the casinghead gasoline, and boosts the pressure of the dry gas, a part of which is used for repressuring and the remainder sold to a gas pipe-line company. When plant operations began, the average gross gasoline content was 0.37 gallon per 1,000 cubic feet, but with decrease in rock pressure that figure has gradually increased to 0.48 gallon. The raw natural gasoline manufactured is fractionated to desired vapor pressure, sent by pipe line to a loading rack on the railroad at Cunningham, and shipped in tank cars. Part of the butane is sold locally for rotary and cable-tool drilling fuel.

The Ordovician gas horizons are the Viola limestone, the Simpson sands and the "Siliceous lime," all of which contain large volumes of gas with a natural gasoline content of 0.41 gallon per 1,000 cubic feet. The hydrogen sulphide content is 30 grains per 100 cubic feet in gas from the Simpson and "Siliceous lime." The Viola gas is sweet gas.

Analysis of the gas obtained from the Viola limestone and from

the "Siliceous lime" in Leisman No. 1 Ordovician test is given in Table II.

TABLE II

	Viola Limestone *Gas From 3,922–3,933 Feet*	*"Siliceous Lime"* *Gas From 4,093–4,195 Feet*
Amount of gas	56,251,000 cubic feet per day	27,000,000 cubic feet per day
Rock pressure (S.I.)	1,375 pounds per square inch	1,385 pounds per square inch
Oxygen	0.0%	0.9%
Carbon dioxide	0.2	0.4
Ethane	18.7	21.2
Methane	71.7	59.3
Residue	9.4	18.2
Total	100.0%	100.0%
Heat value	1,048 B.T.U.	919 B.T.U.
Gross value	30″ at 60°F.	30″ at 60°F.
Sample taken	July 2, 1932	August 25, 1932

EQUIPMENT USED

After completion of a well the derrick is moved away. As all wells flow, no pumping equipment is necessary. Equipment at the well-head consists of only a bradenhead between the $12\frac{1}{2}$-inch surface pipe and the 7-inch oil string, a tubing head equipped with a blow-out preventer, two high-pressure gates used to flow the well either through the casing or tubing, and a choke valve elevated approximately 3 feet above the tubing head.

All wells are equipped with 2-inch, $4\frac{3}{4}$-pound seamless tubing run to a point just below the bottom of the last oil- and gas-producing zone drilled in the particular well.

All high-pressure wells flow through a separator which is located on the lease tank battery. In case of low-pressure wells, each flows into its own elevated separator located at the well. The standard tank battery erected on each lease is made up of one 210-barrel receiving tank and four 250-barrel stock tanks.

LIFTING PRACTICE

All Cunningham field wells flow naturally under back pressure, although some have to be "kicked off" by gas from the field gas system which uses the excess gas from the other Lansing wells. Various top-hole chokes are used. They range in size from $\frac{11}{64}$ inch to $\frac{40}{64}$ inch, and the average choke used is $\frac{20}{64}$ inch.

Bottom-hole chokes were tried on several wells in the early development of the pool. It was found that in reducing the bottom-hole choke to $\frac{32}{64}$ inch or less, the choke invariably clogged with fine

formation particles. When a screen was set in tubing below the choke, the screen clogged. Bottom-hole chokes caused a decrease in oil and an increase in gas production.

REPRESSURING PROGRAM

Return of gas to the structure began January 9, 1936. One to three million cubic feet per day is being put into F. C. Miles No. 4, cen. of the north line of the NE. ¼ of Sec. 30, and its north offset, North Miles No. 3. The repressuring is being undertaken slowly at first to keep the gas from channeling through the oil zones, and in order to observe the effect on the oil producion of wells near the input wells. If repressuring appears to be satisfactory, it is planned to build up the bottom-hole pressures and to maintain them at the most desirable pressure. The project has been under way such a short time that obviously it is too soon to predict the results.

PRORATION PRACTICE

Potential tests by the open-flow method are taken at regular intervals under the supervision of the State Conservation authorities. The potentials are taken on one group of wells at a time with the other wells shut in.

The largest potential for the field was 7,565 barrels per day on January 23, 1934, when 13 wells were producing. On the last test made, the potential for the field was 4,862 barrels per day from 35 wells, which gives an average production of 138.9 barrels per well, and permits an allowable production of 27.61 per cent or 1,342 barrels per day for the field for the month of March, 1936.

WATER DISPOSAL

A salt-water disposal well was drilled 250 feet from the south line and 990 feet from the west line of the SW. ¼ of Sec. 20, where an artesian salt-water sand was encountered at 109–114 feet. A string of 8½-inch pipe was cemented under pressure in this hole in order effectively to shut off the artesian fresh-water sand at 48–50 feet. A string of 6⅝-inch casing was set on top of the salt-water sand and cemented under pressure from the bottom to the surface. This one disposal well took 100 barrels per hour, at practically no pressure, after its completion.

A central oil-treating plant for all wells making water was installed in the fall of 1935. The total amount of salt water from 1,200 barrels of oil production per day is 75 barrels, which is fed into the disposal well by gravity.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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GEOLOGICAL NOTES

NEW "PAY" AT ROCK CROSSING, WILBARGER COUNTY, TEXAS

The Phillips Petroleum Company's W. T. Waggoner Estate well No. 51, located 150 feet south and 150 feet west of the NE. corner of Sec. 44, Block 4, H. & T. C. Ry. Co. Survey, Wilbarger County, Texas, was originally completed by Ed Landreth on December 22, 1925, in the Vernon oil sand at 1,186–1,198 feet with an initial production of 20 barrels.

On January 1, 1937, the Bason Drilling Company rigged up a rotary for deepening this well and on January 27, 1937, casing was cemented at 3,060 feet. Some satuation was encountered at 3,024–3,041 feet, but the best saturation was found at 3,068–3,076 feet and pipe was set 8 feet above this showing. When the plug was drilled with cable tools, the well flowed over the derrick with 1,500 feet of drilling water in the hole, and on February 19, 1937, the well was allowed to flow through a separator into stock tanks and after cleaning itself, flowed for 4 hours at the rate of 96 barrels per hour. The following day it was opened, flowed 212 barrels in 2 hours, and was shut in. The well has not been shot, acidized, or cleaned out. The oil tests 39.6° gravity. The well has been given an allowable of 116 barrels per day.

In the course of deepening this well, the Noble limestone was encountered at 2,263–2,282 feet, and had some saturation. Sands in the Milham group below the Noble limestone showed oil at 2,298–2,303, 2,313–2,318, 2,345–2,349, 2,359–2,362, 2,396–2,398, and 2,422–2,428 feet. The Landreth limestone was found at 2,554 feet, and had saturated zones to 2,628 feet. A hard layer of chert was found at 3,015–3,018 feet which should constitute a good marker for future drilling, as 24 hours and one rock bit were required to drill this 3 feet.

There is of course some conjecture as to the age of this new horizon and the writer is venturing the opinion that it is Canyon in age. Though it may be merely a coincidence, it appears significant that this "pay" is approximately the same distance below the Noble limestone, which many call "Gunsight lime," as the Chalk Hill sand is below "Gunsight lime" at Chalk Hill in Archer County. At any rate the horizon is approximately 500 feet below the top of the Landreth limestone which is considered the top of at least that part of Canyon which is present at Rock Crossing, and is saturated limestone.

On August 9, 1934, the Phillips Petroleum Company completed

Waggoner "N" No. 2, about $\frac{3}{8}$ mile southeast of the discovery well, at a depth of 4,212 feet with cable tools. In this well a showing of oil and gas was found at 3,080 feet. Although a hole full of water was being carried, this showing made several flows, and continued showing throughout the drilling of the well. It was on the strength of this showing of oil that well No. 51 was drilled.

The log of "N" No. 2 furnishes an excellent type log for the Rock Crossing field and suggests possibilities for even deeper production, as oil showings were found at 3,489–3,524, at 3,612, and at 3,885 feet. According to the writer's interpretation of this log, the following major unconformities are probably represented in this well, no consideration being given to movements previous to post-Ellenburger pre-Bend time, when the Red River uplift as a whole probably was initiated.

1. The top of that part of the Ellenburger limestone which is represented is at about 3,850 feet, and a showing of oil was found at 3,885 feet in Ellenburger limestone. The Bend formation rests on Ellenburger and extends upward to about 3,450 feet, with showings of oil in the Marble Falls limestone at 3,489–3,524 and at 3,612 feet. The Bend lying on Ellenburger is a major unconformity for the entire district, with the possibility that some post-Ellenburger pre-Pennsylvanian remnants may be preserved between the two, in which case the Ellenburger top is probably somewhat deeper than 3,850 feet, and more than one unconformity is present between the Ellenburger and Bend.

2. About 900 feet of Canyon rest on Bend, with probably no Strawn sediments present. If any Strawn is present, then only a small amount of Strawn overlapped the Bend unconformity. Since the writer knows of no marked unconformity between the Strawn and Canyon, it is difficult to judge the exact age of those Pennsylvanian beds which did begin to overlap the top of the Bend "high," but it is his opinion that after the deposition of the Bend formation there was a marked disturbance involving some faulting which elevated the Rock Crossing structure, and kept it above sea-level throughout Strawn time and until some part of Canyon time. During this period of erosion, the Bend was apparently completely removed from the tops of many of the "highs" on the so-called Red River uplift, this being the principal major unconformity represented in the log of this well. Possibly the Bend never covered the tops of the Red River uplift "highs," but it appears to be present on the south side and probably was present on the tops, but was eroded off at this time, as was much of the early Paleozoic locally. If not, then it overlapped the flanks of the "highs." Considerable evidence supports this view.

3. Deposition of post-Bend age continued until the close of Canyon time, when another uplift took place subjecting the previously formed "highs" to another period of erosion, and it was during this period of erosion that the Landreth limestone truncated surface was formed. How much of the Canyon was removed from the Rock Crossing structure is problematical, but it varied in other localities, depending on local elevation. No doubt the post-Canyon surface approached a peneplain, reducing the top of the so-called "Big lime" of the Red River uplift in Wichita and Wilbarger counties. So far as the writer knows, this Canyon surface produces oil only in Wilbarger County, Foard County, and near Electra in Wichita County. It is not his intention to take issue at this time with the theory that the "Big lime" is a reef formation, as has been suggested by some. That is simply another point at which there is much argument, and it does not affect the presence of an unconformity at this point.

As the Cisco seas began their advance over the area, Cisco sediments began to overlap the old post-Canyon surface. At Rock Crossing, 250 feet of sediments below Noble (or Gunsight) limestone are present. In other parts of Wilbarger County, Cisco did not overlap the tops of other Canyon "highs" until well on in Cisco time, so that this unconformity constitutes the last major unconformity in the district, and may perhaps have been the most extensive period of erosion, since in some places Cisco rests on Ellenburger and even older beds. Apparently no later extensive unconformities occur after this post-Canyon pre-Cisco period of erosion. Though the writer may be assigning too much importance to the probability of movement of the Red River uplift at the close of Canyon time, considerable evidence points in this direction.

1. The Landreth limestone productive zone has the appearance of a weathered and altered zone, containing chalky material and being very porous, with some cavities as large as a pencil lined with calcite crystals. Off structure the top of the limestone is dry of oil or water.

2. In most places a red bed marks the top of Landreth limestone.

3. Clastic sediments of apparent marine origin and probable Cisco age diverge within short distances from the tops of the Landreth limestone "highs."

4. Basal Cisco sediments are absent from several of the Landreth limestone "highs."

5. It is reported that in southern Oklahoma there is an unconformity of Hoxbar-Pontotoc age which may be correlated with this postulated unconformity.

Correlation of the movements which created these unconformities

with diastrophism in southern Oklahoma would simplify the interpretation of the geology of north Texas.

The discovery of the new "pay" at Rock Crossing should be of great importance to the north Texas district, as a great many wells, particularly in north Wichita County, were abandoned after reaching the "Big lime." A period of deeper drilling in the district is expected soon, and it will probably meet with a reasonable amount of success where intelligently directed. Other pay horizons may be discovered as the result of deeper drilling. In the writer's opinion, the Bend formation offers possibilities for commercial production in some parts of Wilbarger County. The Strawn offers possibilities for oil, particularly in stratigraphic traps, but it will probably be rather deep. Ordovician oil, if present, is most likely to be found north of the axis of the Red River uplift.

It has been suggested by officials of the Phillips Petroleum Company that the name "Rock Crossing limestone" be given the new pay horizon, and the name will probably become generally accepted through common usage.

EARL M. STILLEY

WICHITA FALLS, TEXAS
February 24, 1937

EDITORIAL COMMENT

There are three phases of the subject covered in the preceding note which are controversial at the present writing.

First, there are competent paleontologists who believe that the formation encountered in the Phillips Petroleum Company's Waggoner "N" No. 2 between the depths of 3,450 and 3,850 feet belongs to the Strawn formation rather than the Bend, as indicated in Stilley's note.

Second, the major unconformity which Stilley wishes to place at the top of the Canyon has been shown to exist in the Graham formation of the Cisco, rather than the upper Canyon. This conclusion has been reached after wide regional study of subsurface conditions.

Third, this wide regional study has also resulted in evidence which gives the proponents of the reef theory considerable basis for their opinions.

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REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in Association library and available to members and associates.

Economic Geology of Mineral Deposits. By ERNEST R. LILLEY. Henry Holt and Company, New York. 811 pp., 108 tables, 301 illus. The 811 pages include 22 pages of index. The print, paper, and binding are satisfactory. Price, $5.00.

As stated in the introduction, the main purpose of this book is to correlate the geologic features with the "economic utilization of mineral resources." As it is more comprehensive and more up-to-date than Spurr's "Political and Commercial Geology," published in 1920, it serves a need that has become increasingly apparent, particularly to persons teaching cultural rather than technical undergraduate courses. Anyone attempting to evaluate the past, present, and future relative importance of individual districts will inevitably encounter differences of opinion. Nevertheless, the author has presented a remarkably sound and well balanced, world picture for all the mineral commodities. Thus, the main objective has been obtained in excellent fashion.

The geological information shows evidence of some confusion of purpose. Logically, it should serve, as clearly and simply as possible, as a foundation for the economic deductions. The author, however, has gone beyond this requirement, apparently in an attempt to provide, as an unstated secondary objective, a condensed text on the geology of mineral deposits. The result detracts slightly from the effectiveness of the main objective. Its only advantage from a purely geological viewpoint is the world-wide scope of the entire field. Though on the whole correct, the geological data are not as skillfully presented as in other well known texts.

The book is divided into ten parts, each of which has several sections. Unfortunately, Part I dealing with general principles is the least meritorious, and so is apt to give an erroneous first impression of the value of the book as a whole. It begins with an introduction giving the more important features that distinguish commercially valuable from non-workable mineral aggregates. The meanings of technical terms are clearly explained, rigid definitions being reduced to the background. The author has stated his own use of all terms for which there might be confusion; in most instances he has followed prevailing usage, but in a few cases he has not. Particularly regrettable is the dragging of the term "secondary" from its grave to be expanded to include sedimentary deposits of salt, gypsum, iron ore, *et cetera*. Several statements regarding "tenor," here and elsewhere in the book are misleading. The major part of the next section is devoted to the origin and characteristics of the different types of metallic deposits. It is essentially accurate, yet a few errors appear. On page 21, after reference to Bowen's theory of crystallization-differentiation, the sequence of crystallization in magmas is given as a single line of descent, with "the more basic types of plagioclase" as "typical minerals of the intermediate stages," instead of two (or perhaps three) lines of descent with "basic plagioclase" and pyroxene crystallizing simultaneously. The part dealing with non-metallic deposits is inadequate; and the origin of saline minerals is confusing. A concise discussion of the classification, origin, and

characteristics of rocks could well replace the several pages devoted to the interior of the earth. The author is to be commended for adding a third section on methods of exploitation of minerals.

Part II contains a well rounded and properly proportioned discussion of non-metallic products used in construction. The section on "constructional stone" is exceptionally well done. The one on cement, lime, and plaster stresses utilization rather than geologic occurrence of the raw materials. An excellent résumé of the world distribution of clays compensates for a somewhat inadequate treatment of the physical and chemical properties. Sand and gravel are discussed briefly.

Part III, comprising 142 pages, is quite properly the longest in the book. It deals mainly with coal and petroleum, but natural gas, asphalt, and oil shale are briefly considered. Discussion of the use, classification, properties, origin, mode of occurrence, and methods of extraction of coal is followed by a geographical sketch of coal resources of the world. Emphasis is on the relative importance of the different districts. Petroleum is handled in much the same way. Only the salient features of origin, accumulation, and geological occurrence are touched, but world resources are well discussed. The author is somewhat more than necessarily evasive concerning reserves in this country and omits reference to the possible rôle of hydrogenation of coal. The technical data in this part are prevailingly sound. In places, minor changes would avoid implications that might be challenged, as for example, substituting the words normal and reverse, respectively, for gravity and thrust in the sentence, page 298, "Large commercial pools have been developed adjacent to both gravity and thrust faults."

The first half of Part IV takes up iron ore, pig iron, and steel. The uses of these commodities, the mode of occurrence of the ore, and methods of extraction and treatment are summarized. The manufacture of pig iron and steel is particularly well presented. Then follows a geographical résumé of iron ores of the world, including for each district comments on the geology, the economic importance, and the availability to coking coal; several districts, such as Gellivare and Kursk, having moderate potential importance, are omitted. Brief mention is made of the importance of scrap iron to localities lacking coal and iron ore. Finally, Part IV gives a clear picture of the uses and geographic occurrence of manganese, chromium, tungsten, vanadium, molybdenum, and nickel.

Copper, lead, zinc, tin, aluminum, antimony, and mercury—each individually—are discussed in Part V, in about the same manner as iron and the ferro-alloys. Part VI takes up gold at moderate length and silver briefly. The mode of occurrence and geographic distribution of these metals are clearly and adequately given, but the author passes up an opportunity to contrast the rôle of monetary metals with minerals that are consumed directly in the economic development of a country. Platinum, uranium, radium, and gem stones (almost entirely diamonds) are considered briefly at the end of Part VI.

Sulphur and pyrite, halite, potash, nitrate, and phosphate rock are briefly discussed in Part VII. In contrast to all the other minerals, foreign deposits of phosphate and, particularly, halite are given little space. Still more briefly, yet adequately, feldspar, mica, graphite, bleaching clays, boron, barite, fluorspar, asbestos, magnesite, and talc are included in Part VIII under the

ambiguous title, "The Industrial Minerals." Part IX, which is very short, considers more than twenty rare commodities.

By the time he reached Part X, "Summary and Conclusions," the author apparently concluded that his book was long enough, so failed to develop several topics of a philosophic nature.

Editorial criticisms are of relatively minor significance, yet several may be pointed out. Foremost is that the text refers to only one of the many illustrations and tables. The value of some illustrations is diminished by lack of sufficient explanation or by too much detail. The literary style could be improved by rearranging material to eliminate repetition and to avoid temporarily misleading the reader. For example, on page 699, the first six sentences of a section entitled "Geology of Feldspar Deposits" tell of the widespread occurrence of feldspar and its high percentage in certain rocks; then, the seventh sentence states that these rocks have no commercial value. Pegmatites, the leading source of feldspar, are not mentioned until the thirteenth sentence. Carelessness is evident in places. Thus, on page 76, the author means rate of solution and not solubility in "stability and solubility of the several minerals present vary with the temperature, quantity, and distribution of rainfall, the topography and drainage of the area . . . ." On page 568 appears the remarkable statement that the ore *bodies* (italics by reviewer) of the Witwatersrand have been examined under the microscope by many of the leading geologists of the world. Analogous but less obvious mistakes elsewhere lead to incorrect implications.

In summary, the book is a valuable contribution in a necessary field. Criticisms can be offered, but when relegated to their true importance, they detract only slightly from its merits. It contains under one cover a wealth of information derived from many published sources. It should be particularly useful to persons desiring an evaluated picture of the world distribution and industrial uses of the many minerals entering commerce. Specialists, for example petroleum geologists, will not use it as a reference in their own field but will find it of great value in other fields.

QUENTIN D. SINGEWALD

ROCHESTER, NEW YORK
February, 1937

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*"On Geology of the Gaza-Beersheba District." By L. PICARD and P. SALOMANICA. *Geol. Dept., Hebrew University* (Jerusalem), Sec. 1, Bull. 2 (July, 1936). 44 pp., 1 map, 3 pls., 3 figs. *"Conditions of Underground Water in the Western Emek." By L. PICARD. *Ibid.*, Bull. 1 (July, 1936). 24 pp. in English and 20 pp. in Hebrew, 1 map, 4 cross sections.

These bulletins are the first two published by the geological department of the Hebrew University—one of the youngest of the world's universities. Louis Picard is head of this department and his studies for the past 10 years have been directed largely to the details of stratigraphic geology, as a basis for hydrologic studies. Picard is collecting as complete a set of logs of wells drilled as is possible, for water is as important to Palestine and its development as oil is to most countries.

Both studies are chiefly of value for their addition to the stratigraphic knowledge of the country.

The first paper is the more important of the two, covering a larger area

and a more varied stratigraphy. It covers the region from just north of Gaza southeast to Beersheba and southward. The geologic formations described range from Upper Cretaceous to Recent.

The second paper covers the Valley of the Kishon (only 1,600 square miles), the second most important irrigable area of Palestine. It describes chiefly Alluvial to Pliocene and Cretaceous beds, and some basalt extrusives. The valley itself yields very little water, although the borders of Mount Carmel farther south and of the hills farther north are more promising for water wells.

One other paper recently published also is valuable chiefly for its stratigraphy: "The Stratigraphy of Palestine and Its Building Stones," by C. S. Blake. Blake is geological adviser to the Palestine Government and is now completing some of his areal geologic maps for publication. Both Picard and Blake have done important geologic mapping.

The Picard papers stress faulting too little, though recent detail studies indicate exact location of fault lines is difficult. Electro-geophysical work of the resistivity type has been helpful in outlining more exactly the position of the fault which separates the Coastal Plain Pliocene-Miocene from the Cretaceous limestones. The Kishon Valley has been crossed and recrossed by electro-geophysical profiles and yields little in the way of the low resistive or possible water-bearing horizons. Such work would be valuable in the adjoining hills but is practical only in restricted areas.

F. JULIUS FOHS

HOUSTON, TEXAS
February 22, 1937

"The Pleistocene Fauna of Magdalena Bay, Lower California." By ERIC KNIGHT JORDAN, with an introduction by LEO GEORGE HERTLEIN. *Contributions from the Department of Geology of Stanford University*, Vol. 1, No. 4 (November 13, 1936), pp. 105–73, Pls. 17–19.

This posthumous contribution from the pen of Eric Knight Jordan (whose decease occurred March 10, 1926) was capably edited by L. G. Hertlein of the California Academy of Sciences. In a short introduction Hertlein briefly reviews previous literature on the Pleistocene fauna of Magdalena Bay, Lower California, Mexico. The paper itself has been kept "the work of Jordan as much as possible" though Hertlein has made certain changes and additions necessitated by a decade of progress in paleontology and conchology since the demise of the author.

Jordan lists (and in some cases discusses and figures) over 400 definitely identified species or subspecies of Mollusca collected from the richly fossiliferous but relatively thin upper Pleistocene deposits exposed just north and south of the village of Magdalena Bay and on Margarita Island in Magdalena Bay, Lower California, Mexico. Eighteen of the figured species are described as new. This is truly a huge fauna, the identification of which required much laborious study of scattered and often rare papers on conchology. The synonymy of the species discussed and the footnotes are very helpful in guiding future students of west Mexican conchology.

In the introduction Hertlein states that about 95 per cent of the species are known to be living in the west American seas to-day. He states further that

The fauna is decidedly tropical in character and corresponds in general to the warm-water Upper San Pedro fauna described from California by Ralph Arnold. Many of the species are now found living in the Gulf of California. The species represent a fauna of near-shore character.

The following sixteen new species are described and figured: *Crassinella goldbaumi; Gafrarum (Gouldia) stephensae; Sportella duhemi; Anisodonta peninsulare; Terebra magdalenensis; Mangelia wrighti; Crassispira kluthi; Turbonilla (Pyrgiscus) beali; Odostomia (Chrysallida) eiseni; O (C). evermanni; Cerithiopsis lohri; Gyrineum strongi; Alvania contrerasi; Tegula eiseni; Rissoina hartmanni; Teinostoma gallegosi.*

From a mechanical or physical standpoint the paper upholds the high quality reputation of the Stanford University Press.

U. S. GRANT

UNIVERSITY OF CALIFORNIA AT LOS ANGELES
March 3, 1937

RECENT PUBLICATIONS

ALASKA

*"Latent Oil Resources of Alaska May Be of Importance," by Philip S. Smith. *Oil Weekly* (Houston), Vol. 84, No. 11 (February 22, 1937), pp. 82–84, 88, 90, 94; 4 illus.

AUSTRALIA

*"Geology's Role in the Exploration for Oil in Australia," by Eric A. Rudd. *Oil Weekly* (Houston), Vol. 84, No. 11 (February 22, 1937), pp. 122, 124; 1 map.

BRAZIL

*"Future Oil Possibilities of Virgin Regions Calls for Drilling in Brazil," by Victor Oppenheim. *Oil Weekly* (Houston), Vol. 84, No. 11 (February 22, 1937), pp. 108, 110, 112, 114, 116, 121; 6 illus., 2 tables.

CENTRAL AMERICA

"Mittelamerika" (Central America), by Karl Sapper with the coöperation of Walther Staub. *Handbuch der Regionalen Geologie* (Carl Winter, Heidelberg), Vol. 8, Div. 4a, No. 29 (1937). 160 pp., 15 figs., 11 pls.

CHINA

*"Oil Prospecting in Szechuan Province," by C. H. P'an. *Oil Weekly* (Houston), Vol. 84, No. 11 (February 22, 1937), pp. 134, 138, 142, 144, 146; 3 figs., 1 map.

FRANCE

*"Les Bryozoaires du Coniacien des Charentes (sensu lato)" (The Bryozoans of the Coniacien of Charentes), by Roger Allegre. *Bull. Geol. Soc. France* (Paris), Ser. 5, Vol. 6, Nos. 1, 2, 3 (1936), pp. 87–107.

GENERAL

Petroleum and Natural Gas Bibliography, by Robert E. Hardwicke. About 175 pages. Published under the auspices of the Department of Petroleum Engineering and the School of Law, University of Texas, Austin, Texas. Orders may be sent to the University of Texas. Major headings are: General

and Historical; Finding and Prospecting; Development and Production; Transportation and Storage; Refining, Analysis and Testing of Petroleum, Natural Gas and Their Products; Marketing and Utilization of Petroleum, Natural Gas and Their Products; Economics and Statistics; Legal; Hearings, Investigations, Reports and Findings of Political Nature by Branches of Congress, Departments and Bureaus of the Government of the United States; Accounting and Finance; Bibliographies, Indexes and Lists of Publications.

*"Structural Trends May Furnish Clews to Future Oil Fields," by W. V. Howard. *Oil and Gas Jour.* (Tulsa), Vol. 35, No. 39 (February 11, 1937), pp. 28–30; 6 figs.

**National Research Council, Division of Geology and Geography, Annual Report for 1935–1936.* (Washington, D. C., December, 1936.) 214 pp. Report includes membership of division and its committees, minutes of the annual meeting, the annual report of the chairman, the reports of the committees, and organization of committees.

Oil and Gas Operating Regulations applicable to lands of the United States and to all restricted tribal and allotted Indian land (except Osage Indian Reservation); revised November 1, 1936 (January, 1937). iv, 26 pp. Price, 10 cents. May be purchased from Supt. of Documents, Govt. Printing Office, Washington, D.C.

*"Petroleum Genesis: Geologic Distillation vs. Contemporaneity Hypothesis," by Francis M. Van Tuyl and Ben H. Parker. *Pan-American Geol.* (Des Moines, Iowa), Vol. 67, No. 2 (March, 1937), pp. 109–16.

*"Studying Present Earth Surface Reveals Past Geologic History," by W. V. Howard. *Oil and Gas Jour.* (Tulsa), Vol. 35, No. 42 (March 4, 1937), pp. 13–14, 22; 2 figs.

GEOPHYSICS

*"A Method of Testing Reflection Seismographs," by J. H. Jones. *Jour. Inst. Petrol. Tech.* (London), Vol. 23, No. 159 (January, 1937), pp. 26–31; 3 figs.

*"The Use of Reversed Refraction Arcs in Seismic Surveying," by R. Davies. *Ibid.*, pp. 31–39; 2 figs.

*"Exploration by the Reflection Seismograph in the Gulf Coast of Texas and Louisiana," by E. E. Rosaire. *Ibid.*, pp. 40–56; 5 figs.

*"Geophysical Exploration of East Indies Conducted Under Great Difficulties," by Neil Williams. *Oil and Gas Jour.* (Tulsa), Vol. 35, No. 40 (February 18, 1937), pp. 53–54; 2 illus.

*"Geophysics—Its Application to Petroleum Prospecting," by J. Brian Eby. *Petrol. Engineer* (Dallas, Texas), Vol. 8, No. 5 (February, 1937), pp. 113–34; 32 figs.

*"Use of Multiple Seismometers," by Eugene McDermott. *Ibid.*, pp. 135–36; 3 figs.

*"Instruments and Operating Procedure in Geophysical Prospecting by Gravity Methods," by G. Stubbe and K. H. Schmidt. *Ibid.*, pp. 137–39; 6 figs.

*"Applications of the Geo-Sonograph to Petroleum Exploration," by Frank Rieber. *Ibid.*, 141–42; 6 figs.

*"Prospecting for Oil Structures by Electrical Methods," by J. J. Jakosky and C. H. Wilson. *Ibid.*, pp. 143–47; 8 figs., 1 table.

"Geophysical Regional Surveys as the Basis for Discovery of New Oil

Deposits," by O. Barsch. Read before the German Society for Mineral Oil Research, Berlin, 1936.

GERMANY

*"Die Kreideablagerungen zwischen Elbe und Jeschken—Teil III: Die Fauna der obersten Kreide in Sachsen, Böhmen und Schlesien" (The Cretaceous between the Elbe and Jeschken—Part III: The Fauna of the Uppermost Cretaceous in Saxony, Bohemia and Silesia), by Hermann Andert. *Prussian Geol. Survey* (Berlin), No. 159 (1934). 477 pp., 19 pls., 6 tables, 102 figs.

*"Die Arthropoden aus dem Carbon und Perm des Saar-Nahe-Pfalz-Gebietes" (The Arthropods in the Carboniferous and Permian of the Saar-Nahe-Pfalz District), by Paul Guthörl. *Ibid.*, No. 164 (1934). 219 pp., 116 figs., 30 pls.

*"Die Geologie des Gebietes von Weidenberg-Goldkronach" (The Geology of the Weidenberg-Goldkronach District), by Karl Goller. *Ibid.*, No. 165 (1935). 121 pp., 7 figs., 1 map.

*"Paläobotanische und kohlenpetrographische Studien in der nordwestdeutschen Wealdenformation" (Paleobotanical and Coal Petrographical Studies in the Northwest German Wealden Formation), by Ferdinande Michael. *Ibid.*, No. 166 (1936). 79 pp., 4 pls.

*"Die fauna der Obersten Siegener Schichten von der Unkelmühle bei Eitorf a. d. Sieg" (The Fauna of the Uppermost Siegener Beds of the Unkelmühle near Eitorf on the Sieg), by Georg Dahmer. *Ibid.*, No. 168 (1936). 36 pp., 6 pls., 2 figs.

HOLLAND

*"Lack of Surface Indications Calls for Combined Geology and Geophysics to Determine Holland's Future Among Oil Producing Nations of the World," by Theo Reinhold. *Oil Weekly* (Houston), Vol. 84, No. 11 (February 22, 1937), pp. 96, 98; 1 illus.

*"Netherlands Responsible for Core Drilling Method Used in Modern Exploration," by W. A. J. M. van Waterschoot van der Gracht. *Ibid.*, pp. 184, 186.

ILLINOIS

*"Illinois' Future Improved—Recent Leasing Play and Geological Conditions Indicate Good Possibilities," by Homer Easley. *Oil Weekly* (Houston), Vol. 84, No. 12 (March 1, 1937), pp. 40–43; 1 map.

INDO-CHINA

"Les Fusulinidés du Permien de l'Indochine Leur structure et leur classification" (The Fusulinids of the Permian of Indo-China. Their Structure and Their Classification), by J. Gubler. *Geol. Soc. France* (*N. S.*) (Paris), Vol. 11, No. 4, Mem. 26. 172 pp., 8 pls. Price, 100 Frs.

MEXICO

*"Quelques nouveaux Échinides fossiles du Crétacé du Mexique" (Some New Echinoid Fossils of the Cretaceous of Mexico), by J. Lambert. *Bull. Geol. Soc. France* (Paris), Ser. 5, Vol. 6, Nos. 1, 2, 3 (1936), pp. 3–6; 1 pl (8 figs.).

MISSOURI

*"Fifty-Ninth Biennial Report of the State Geologist, 1937," by H. A. Buehler. *Missouri Geol. Survey and Water Resources* (Rolla, Missouri).

*"The Dutchtown, A New Lower Ordovician Formation in Southeastern Missouri," by H. S. McQueen. *Ibid.*, Appendix I. 27 pp., 5 pls., 1 fig.

*"The St. Louis Formation in Southwestern Missouri," by Edward L. Clark. *Ibid.*, Appendix IV. 13 pp., 2 figs.

*"The Cheltenham Clay of Missouri," by Victor T. Allen. *Ibid.*, Appendix V. 29 pp., 5 pls.

*"The Geology of Stoddard County, Missouri," by Willard Farrar and Lyle McManamy. *Ibid.*, Appendix VI. 92 pp., 12 pls., 2 figs., 7 tables.

*"Oil and Gas Possibilities in the Fillmore Area, Andrew County, and the Gower Area, Clinton and Buchanan Counties," by F. C. Greene, J. R. Clair, and H. S. McQueen; and "Oil and Gas Developments in Missouri, in 1935–1936," by F. C. Greene. *Ibid.*, Appendix VIII. 34 pp., 1 fig., 2 pls.

NEW GUINEA

*"Wave of Activity Should Yield Results Important to New Guinea," by D. Dale Condit. *Oil Weekly* (Houston), Vol. 84, No. 11 (February 22, 1937), pp. 178–80, 182; 1 map.

NEW YORK—ONTARIO

*"Stratigraphy of the Trenton Group," by G. Marshall Kay. *Bull. Geol. Soc. America* (New York), Vol. 48, No. 2 (February 1, 1937), pp. 233–302; 13 figs., 10 pls.

OKLAHOMA

"Possibility of New Oil Pools in the Siliceous Lime and Bartlesville Sand in T. 23 N., R. 10 E., Osage County, Oklahoma," by N. W. Bass, W. R. Dillard, and J. H. Hengst. *U. S. Geol. Survey Bull. 886–A* (January, 1937), pp. i-ii, 1–4, Fig. 1. Price, 5 cents. May be purchased from Supt. of Documents, Govt. Printing Office, Washington, D.C.

*"Geology of the Fitts Pool in Oklahoma," by K. R. Teis and Maurice Teis. *Oil Weekly* (Houston), Vol. 84, No. 12 (March 1, 1937), pp. 18–20, 22, 24 26; 6 figs., 1 table. This is a discussion of Part I of a paper, "Geology and Development of the Fitts Pool," read at the meeting of the Mid-Continent District of the American Petroleum Institute, Division of Production, at Tulsa, February 25, 26. This part includes the authors' discussion of the interesting geology of this section with its several producing strata.

*"The Fitts Pool—Its Geology and Development," by K. R. Teis and Maurice Teis. *Oil and Gas Jour.* (Tulsa), Vol. 35, No. 42 (March 4, 1937), pp. 42, 44, 45; 4 pls.

PENNSYLVANIA

"Geology and Mineral Resources of the Butler and Zelienople Quadrangles, Pennsylvania," by G. B. Richardson. *U. S. Geol. Survey Bull. 873* (January, 1937), v, 93 pp., 8 pls., 10 figs. Price, 45 cents. May be purchased from Supt. of Documents, Govt. Printing Office, Washington, D.C.

POLAND

*"Reflection Seismology in Exploring for Potential Fields in Poland," by Z. A. Mitera. *Oil Weekly* (Houston), Vol. 84, No. 11 (February 22, 1937), pp. 164, 168, 172, 176; 7 figs.

*"Budowa Geologiczna Okolic Zabiego" (Geologic Structure in the Neighborhood of Zabie), by H. Teisseyre. *Carpathian Geol. Inst.* (Warsaw-Boryslaw-Lwow) *Bull. 28* (1936). 36 pp., geological map. In Polish and French.

ROCKY MOUNTAINS

**Resume Rocky Mountain Oil and Gas Operations for 1936.* Published by Petroleum Information, Inc., Denver, Colorado (February, 1937). 125 pp., maps, tables. This is the 9th volume of a series of annual publications which present such facts about oil and gas developments as are of general interest. Practically all of the material used has been taken from weekly, monthly, and special petroleum information reports, but some of it has been generously contributed by others.

RUSSIA

*"New Data on the Tectonics of the Northern Marginal Part of the Donetz Basin," by V. S. Popov. *Problems of Soviet Geology* (Moscow), Vol. 6, No. 12 (1936), pp. 1025–43; 14 figs. In Russian. Summary in English.

*"On the Present Uplifting of the Khodja-k-Kan Salt Dome and the Possibility of an Analytical Determination of the Rate of the Uplift," by A. P. Koroleva and I. P. Sharapov. *Ibid.*, pp. 1044–52; 2 tables. In Russian. Summary in English.

*"On the Correlation of the Mesozoic Fresh-Water Deposits of Transbaikalia with the Morrison Formation of North America," by O. M. Kichighina. *Ibid.*, pp. 1053–56. In Russian.

*"On the Correlation of the Tertiary Deposits of the Kara-tau Region with those of the Adjacent Regions of Middle Asia and Kazakhstan," by T. A. Mordvilko. *Ibid.*, 1057–66; 1 table. In Russian. Summary in English.

*"On the Stratigraphy of the Tertiary of Sakhalin Island," by A. N. Krishtofovich. *Ibid.*, pp. 1067–71. In Russian. Summary in English.

*"Paleontological Notes on the Carboniferous and Permian Ammonoids," by V. E. Ruzencev. *Ibid.*, pp. 1072–88; 5 figs. In Russian. Summary in English.

*"On the History of the Great Caucasus during the Upper Jurassic and Lower Cretaceous Time," by V. V. Belousov. *Ibid.*, Vol. 7, No. 1 (1937), pp. 1–24; 5 figs. In Russian. Summary in English.

*"Stratigraphy and Fauna of the Tertiary Deposits of Western Coast of Kamchatka," by W. S. Slodkewitsch. *Trans. Geol. Oil Inst.* (Leningrad, U. S. S. R., Vas. Ostrov. Tuckkova nab. 2), Ser. A, No. 79 (1936). 202 pp., 18 pls. with many figs., many tables. In Russian. Summary in English.

*"Über die Lagerungsverhältnisse des Erdöls im Fergana-Gebiete" (On the Stratigraphic Relations of Petroleum in the Fergana Region), by K. Kalicki. *Ibid.*, No. 73 (1936). 52 pp., 14 figs. In Russian. Summary in German.

*"An Account of the Geological Investigations in Bolshye and Malye Shiraki District (sheet XXIX–41) in 1930–31," by Z. L. Maymin. *Ibid.*, No. 78 (1936). 66 pp., 1 table, 1 map. In Russian. Summary in English.

*"Entstehung und Lagerungsverhältnisse des Erdöls im Fergana-Gebiete" (Origin and Stratigraphic Relations of Petroleum in the Fergana Region), by K. Kalicki. *Ibid.*, No. 89 (1936). 44 pp., 12 figs. In Russian. Summary in English.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 21, NO. 4 (APRIL, 1937) PP. 538-542, 1 FIG.

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

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HANS STILLE, HONORARY MEMBER

Professor Hans Stille is perhaps best-known for his volume on the fundamental problems of comparative tectonics, in which he did much to stimulate

Hans Stille

interest in some important geological problems. He has contributed publications to the elucidation of German geology, and has done much to stim-

ulate geologic research in many regions beyond the borders of Germany. He has recently been hard at work upon the revision of the book on comparative tectonics.

He received his doctor's degree from the University of Göttingen in 1899 and taught in that institution until about five years ago. He has more recently been professor of geology at the University of Berlin.

He is well known to Association members because of his frequent contributions to the *Bulletin* and also because of his extensive travels in the United States on different occasions. His work is of interest to them not only because it has involved contributions to petroleum geology in the narrow sense, but also and chiefly because it has dealt so largely with the phase of tectonics that underlies so much of their own work.

Professor Stille's 60th birthday, October 8, 1936, was celebrated by the publication of a Festschrift containing articles on many of the geological subjects of most interest to him. His election to honorary membership at this time, it is hoped, will be accepted as another expression of the spirit that led the geologists of his immediate circle to prepare the Festschrift.

COMPREHENSIVE INDEX

The *Comprehensive Index* of 20 volumes of the *Bulletin* and all special publications of the Association from 1917 to 1936, inclusive, compiled by Miss Daisy Winifred Heath, editorial secretary, is ready for distribution after more than a year of full-time work by the compiler and several assistants. This important contribution of the Association to the science of geology will soon be sent free and postpaid, to each paid-up member and associate member.

Members and associates may obtain additional copies at $2.00, postpaid. This *Index* is also available to non-members at $3.00 per copy, postpaid, by writing Association headquarters, Box 1852, Tulsa,Oklahoma.

L. C. Snider introduces the *Index* with an editorial note, the first paragraph of which is here quoted.

> The publication of this *Comprehensive Index* may be taken as a memorial to the accomplishments of The American Association of Petroleum Geologists during the first twenty years of its existence. The twenty volumes of the *Bulletin* and the special publications contain a contribution not only to petroleum geology in a strict sense of the term but also to the science of geology in its broader aspects of which every member of the Association may well be proud. Certainly, the contribution of the Association to geology compares favorably with that made by any similar society to any of the sciences in an equal length of time.

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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 21, NO. 4 (APRIL, 1937), PP. 543-544, 1 FIG.

Memorial

ED DICKINSON WAPPLER

Ed Dickinson Wappler, geologist for The Superior Oil Company of California, died suddenly in Shreveport, Louisiana, January 18, 1937, a few days after an emergency appendectomy.

He was born in Shreveport, December 10, 1908, the only child of Fred and the late Kate Shields Wappler. He attended the public schools in Shreveport and entered Louisiana State University in the fall of 1925, where he received the Bachelor of Science degree in geology in June, 1930, and spent an additional year doing research work in micropaleontology. He continued his research study in Shreveport until the fall of 1932, when he became associated

ED DICKINSON WAPPLER

with E. A. Stiller, consulting geologist, as geologist and paleontologist, and did consulting work for the Century Oil and Drilling Company, Larkin and Warr, and others. On June 1, 1936, he accepted a position as assistant geologist and scout with The Superior Oil Company of California in the Shreveport office, which position he held at the time of his death.

Ed was endowed with an exceptional personality, and his honesty, sincerity, fine sense of humor, and genial nature endeared him to all who knew him. He leaves a host of friends to whom his death comes as a distinct loss. He was a hard and conscientious worker and a good mixer. He was personally

acquainted with almost everyone connected with the exploration division of the oil industry in the Shreveport district. His contacts and geological knowledge of this district made him an extremely valuable man to his company.

Ed was an associate member of the American Association of Petroleum Geologists and a member of the Shreveport Geological Society, Shreveport Oil Scouts Association, Louisiana Academy of Science, and Geological and Mining Society of American Universities. He was a first lieutenant in the Reserve Officers Association of the United States and a member of the Sigma Chi fraternity, The Daggers, and Scabbard and Blade.

GARLAND O. GRIGSBY

LAKE CHARLES, LOUISIANA
March 4, 1937

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 21, NO. 4 (APRIL, 1937) PP. 545-548

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

J. J. RUSSELL, geologist for the Texas Pacific Coal and Oil Company, Midland, Texas, has resigned to accept a similar position with the Sinclair Prairie Oil Company, Midland.

F. E. HEATH, geologist for the Sun Oil Company, Dallas, Texas, has been appointed a member of the special study committee on well spacing of the American Petroleum Institute's division of production.

D. V. CARTER, chief petroleum engineer for the Magnolia Petroleum Company, Dallas, Texas, has been appointed a member of the engineers' subcommittee of the American Petroleum Institute's division of production committee on the standardization of wire rope and manila cordage.

ALFRED C. LANE, professor emeritus of geology at Tufts College, lectured before the Society of Sigma Xi at the Ohio State University, January 7, on "Measurement of Geologic Time." He also spoke before the geological department of the university, January 6 and 7, on "Radio-active Methods Applied to Pre-Cambrian Classification" and "Principles of Economic Geology."

D. C. SHAY has resigned as district geologist for the Devonian Oil Company at Shreveport and has joined the firm of Taubert and McKee, Fort Worth, as head of the land and geological department. Taubert and McKee have been drilling contractors, but are entering the production business under the name of Vindicator Petroleum Company.

L. T. BARROW, chief geologist of the Humble Oil and Refining Company, was elected a director of the company, February 8.

RAYMOND F. MCMILLEN has resigned from the Turman Oil Company to become geologist for the Coralena Oil Company, 606 Cosden Building, Tulsa, Oklahoma.

C. W. SANDERS, recently returned from The Hague and temporarily with the Shell Oil Company, may be addressed at his residence, 6520 Drexel Avenue, Los Angeles. He expects to return to Houston later in the year.

E. R. BROCKWAY is in charge of the district offices of the Devonian Oil Company, Shreveport, Louisiana. He may be addressed at Box 1575.

GLEN WOOLLEY, Kansas geologist for the past 9 years, has been put in charge of the Kansas exploration activities of the Transwestern Oil Company, Oklahoma City, with headquarters at 814 Union National Bank Building, Wichita, Kansas.

The San Antonio Geological Society elected the following officers at its annual meeting February 15: president, HARRY NOWLAN, South Texas representative for Darby Petroleum Corporation, San Antonio; vice-president,

W. A. MALEY, of the Humble Oil and Refining Company, Corpus Christi; secretary-treasurer, STUART MOSSOM, of the Magnolia Petroleum Company, San Antonio; and to the executive committee, C. C. MILLER, of The Texas Company, Corpus Christi.

T. R. BANKS, geologist, is now with the Transwestern Oil Company, Oklahoma City, and is establishing a district office in the M. & P. Building, Corpus Christi. He will take charge of exploration work in southwest Texas. W. R. MEANS, former East Texas geologist for the Sinclair Prairie Oil Company, has been employed as geological scout for the southwest Texas district.

The American Institute of Mining and Metallurgical Engineers elected as chairman of the petroleum division (and chairman of the division's executive committee), M. ALBERTSON, chief petroleum research engineer of the Shell Petroleum Corporation, Houston; associate chairman, R. P. MCLAUGHLIN, general manager of the Burnham Exploration Company, Los Angeles; secretary-treasurer, EUGENE A. STEPHENSON, professor of petroleum engineering, University of Missouri School of Mines, Rolla, Missouri; members of the executive committee, C. E. BEECHER, chief engineer, Empire Oil and Refining Company, Bartlesville, Oklahoma; L. L. FOLEY, petroleum engineer and geologist, Tulsa; R. B. KELLY, assistant division manager, The Pure Oil Company, Fort Worth; HALLAN N. MARSH; and R. E. SOMERS, Gulf Oil Corporation, Pittsburgh. T. V. MOORE, in charge of the production research and technical development division of the Humble Oil and Refining Company, Houston, was elected vice-chairman for production engineering. Associate vice-chairmen are JOSEPH CHALMERS, petroleum and exploitation engineer, Shell Petroleum Corporation, Houston; M. L. HAIDER, petroleum engineer, The Carter Oil Company, Tulsa; EMILE HUGUENIN, deputy state oil and gas supervisor, Los Angeles; and CARL E. REISTLE, JR., engineer, Humble Oil and Refining Company, Houston. JAMES TERRY DUCE, geologist with The Texas Company, New York, was re-elected vice-chairman for production. He will be assisted by vice-chairman, BASIL B. ZAVOICO, petroleum engineer with the Chase National Bank, New York. R. L. HUNTINGTON, associate professor of petroleum engineering, University of Oklahoma, Norman, was elected vice-chairman for engineering research. SYDNEY A. SWENSRUD, assistant to the president of the Standard Oil Company of Ohio, was re-elected vice-chairman for economics. WALTER MILLER, vice-president of the Continental Oil Company, was re-elected vice-chairman for refinery engineering and EARL OLIVER, appraisal engineer of Ponca City, was re-elected vice-chairman of the stabilization committee.

L. I. YEAGER, district geologist for the Empire Oil and Refining Company in Kansas, has been transferred to a similar position in West Texas and New Mexico. Z. E. STUCKY was transferred from Oklahoma City to Wichita, Kansas, succeeding Yeager.

N. B. WINTER, head of the geological department of the Atlantic Refining Company's West Texas division, has moved from San Angelo to Midland, where offices have been taken in the Petroleum Building.

JOSEPH S. IRWIN, geologist, is moving his consulting offices to 812 Lancaster Building, Calgary, Alberta.

L. L. FOLEY, division production engineer for the Ohio Oil Company, Tulsa, resigned March 15 to enter consulting engineering and geological work. His offices will be at 2400 National Bank of Tulsa Building, Tulsa.

OSCAR HATCHER, geologist and independent operator, Ada, Oklahoma, was re-elected vice-chairman for Oklahoma of the Mid-Continent Section, Production Division, of the American Petroleum Institute.

DARWIN BENEDUM, geologist, and his brother, J. C. BENEDUM, have opened offices in the Milam Building, San Antonio, Texas.

M. B. STEPHENSON, former professor at the Louisiana State University, has moved from Baton Rouge to Fort Worth to become paleontologist for the Sinclair Prairie Oil Company in the Fort Worth division.

E. G. THOMPSON recently addressed the Dallas Petroleum Geologists, giving a detailed subsurface interpretation of the Talco field. He also was the principal speaker at the March meeting of the Shreveport Geological Society, his subject being on the fault line of north Texas, with special reference to the Talco and Sulphur Bluff fields.

J. R. JONES, subsurface geologist of the Shell Petroleum Corporation, has been transferred from Wink to Midland, Texas.

E. Leitz, Inc., announces the removal of its headquarters in New York from 60 East 10th Street to the Heckscher Building, 730 Fifth Avenue. The new quarters are exceptionally well suited for carrying on its extensive business in microscopes and other optical instruments, as well as the well known Leica cameras. Included are a large display room, a well equipped projection and demonstration room, and many new facilities for increasing service to customers A modern, well equipped machine shop is available for the repairing and servicing of all optical instruments, both of the microscope and Leica line.

At the February meeting of the Kansas Geological Society, held at the Allis Hotel, Wichita, ROY H. HALL, consulting geologist of Wichita, addressed the society on "Isopachous Studies of the Central Kansas Uplift."

GEORGE R. WESLEY has resigned from the Kentucky Department of Mines and Minerals and is now connected with Snowden and McSweeney Company as geologist for the Kentucky and Indiana district. His address is 703 Griffith Avenue, Owensboro, Kentucky.

WILL F. EARL has been transferred to the Tulsa office of The Ohio Oil Company. His address is 35 North Victor, Tulsa.

JOHN R. BALL, of the department of geology and geography of Northwestern University, delivered the following exchange lectures before the University of Kansas department of geology, March 16, 17, and 18, 1937: "Late Cambrian Rocks of the Upper Mississippi Valley," "Cambro-Ordovician Problems of the Upper Mississippi Valley," "The Mississippi River," and "The Silurian System in the Mississippi Valley."

LON B. TURK, petroleum geologist-engineer, presented a paper on "Resume of Oklahoma City Field—Study of Minor Folds, Ultimate Recovery,

and Production Problems," at the meeting of the Tulsa Geological Society, March 15.

E. A. Wahlstrom, Fort Worth division engineer for the Stanolind Oil and Gas Company, has resigned to become chairman of the Engineering Committee created by operators in the Goldsmith field, West Texas. He will be succeeded by George C. Card, petroleum engineer of the Tulsa division of the Stanolind Oil and Gas Company.

The Association of American State Geologists has elected the following officers for the year beginning March 1: president, Arthur Bevan, State geologist of Virginia; vice-president, Walter F. Pond, State geologist of Tennessee; and secretary, Raymond C. Moore, State geologist of Kansas. These representatives were also elected: to the National Research Council, Henry B. Kummel, State geologist of New Jersey, on the Division of States Relations, and Henry A. Buehler, State geologist of Missouri, on the Highway Research Board; to the Federal Board of Surveys and Maps, Edward B. Mathews, State geologist of Maryland; Washington, D. C., representative, George H. Ashley, State geologist of Pennsylvania.

E. G. Gaylord, of the Standard Oil Company of California, has been appointed chairman for 1937 of the American Petroleum Institute's advisory committee on fundamental research on occurrence and recovery of petroleum.

Russell Johnson, of Calgary, Alberta, Canada, has been named consulting geologist of the Marine Petroleum, Limited, organized in Winnipeg, to drill for oil in the Turner Valley field. Robert McKay, Winnipeg broker, heads the new company.

R. C. Kerr has joined the geophysical division of the geology department of the Standard Oil Company of California and may be addressed in care of the company, Box 1200, Bakersfield, California.

W. E. Heater of Batavia-C., Java, has changed his address to 225 Bush Street, San Francisco, California.

The Society of Economic Paleontologists and Mineralogists, division of the American Association of Petroleum Geologists, has elected the following officers for the coming year: president, G. Stanley Wissler, chief paleontologist, Union Oil Company, Los Angeles; vice-president, F. W. Rolshausen, Humble Oil and Refining Company, Houston; secretary-treasurer, Henry V. Howe, department of geology, University of Louisiana.

The Society of Exploration Geophysicists elected the following officers for the year: president, J. C. Karcher, Dallas; vice-president, F. M. Kannenstine, Houston; secretary-treasurer, M. E. Stiles, Houston; editor, M. M. Slotnick, Houston. Wallace E. Pratt and L. P. Garrett, were elected honorary members of the society.

By error in the membership list in the March *Bulletin*, page 387, the years of joining the Association were transposed following the names of James E. Gunn and Herman Gunter. Gunn joined in 1933 and Gunter in 1921.

PROFESSIONAL DIRECTORY

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2nd Vice-President - - - W. O. Thompson
University of Colorado
Secretary-Treasurer - - - J. Harlan Johnson
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Luncheon meetings, first and third Mondays of each month, 6:15 P.M., Auditorium Hotel.

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Vice-President - - - - - - A. E. Cheyney
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Secretary-Treasurer - - - - Virgil B. Cole
Gulf Oil Corporation

Regular Meetings: 7:30 P.M., Allis Hotel, first Tuesday of each month. Visitors cordially welcomed.

The Society sponsors the Kansas Well Log Bureau which is located at 412 Union National Bank Building.

LOUISIANA

THE SHREVEPORT GEOLOGICAL SOCIETY
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The Hunter Company, Inc.
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Arkansas Fuel Oil Company

Meets the first Friday of every month, Civil Courts Room, Caddo Parish Court House. Luncheon every Friday noon, Caddo Hotel.

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Vice-President - - - - - Ed I. Thompson
Phillips Petroleum Company
Secretary-Treasurer - - - Don O. Chapell
Shell Petroleum Corporation

Meetings: First Tuesday of each month, from October to May, inclusive, at 7:30 P.M., Dornick Hills Country Club.

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OKLAHOMA CITY, OKLAHOMA

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Ohio Oil Company, Edmond
Vice-President - - - - - - E. A. Paschal
Coline Oil Company
Secretary-Treasurer - - - - - H. L. Crockett
Colcord Building

Meetings: Second Monday, each month, 8:00 P.M., Commerce Exchange Building. Luncheons: Every Monday, 12:15 P.M., Commerce Exchange Building.

SHAWNEE GEOLOGICAL SOCIETY
SHAWNEE, OKLAHOMA

President - - - - - - - Jack M. Copass
Amerada Petroleum Corporation
Vice-President - - - - - - Don L. Hyatt
Carter Oil Company
Secretary-Treasurer - - - - - M. C. Roberts
The Texas Company

Meets the fourth Monday of each month at 8:00 P.M., at the Aldridge Hotel. Visiting geologists welcome.

THE STRATIGRAPHIC SOCIETY OF TULSA
TULSA, OKLAHOMA

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The Pure Oil Company
Vice-President - - - - Constance Leatherock
The Tide Water Oil Company
Secretary-Treasurer - - R. V. Hollingsworth
Shell Petroleum Corporation, Box 1191

Meetings: Second and fourth Wednesdays, each month, from October to May, inclusive, at 8:00 P.M., third floor, Tulsa Building.

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Peerless Oil and Gas Company
Secretary-Treasurer - - - - - - Clark Millison
McBirney Building
Editor - - - - - - - - - Clyde G. Strachan
Gulf Oil Corporation

Meetings: First and third Mondays, each month, from October to May, inclusive, at 8:00 P.M., fourth floor, Tulsa Building. Luncheons: Every Thursday, fourth floor, Tulsa Building.

SOCIETIES

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Secretary-Treasurer - - - - - - R. A. Stehr
Texas Seaboard Oil Company

Meetings will be announced.

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FORT WORTH, TEXAS

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Fort Worth National Bank Building

Vice-President - - - - - - - A. L. Ackers
Stanolind Oil and Gas Company

Secretary-Treasurer - - - M. E. Upson
Gulf Oil Corporation

Meetings: Luncheon at noon, Worth Hotel, every Monday. Special meetings called by executive committee. Visiting geologists are welcome to all meetings.

HOUSTON GEOLOGICAL SOCIETY
HOUSTON, TEXAS

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Houston Oil Company of Texas

Vice-President - - - - - - - O. L. Brace
813 Second National Bank Building

Secretary-Treasurer - - Wallace C. Thompson
General Crude Oil Company, Esperson Building

Regular meetings, every Thursday at noon (12:15) at the Houston Club. Frequent special meetings called by the executive committee. For any particulars pertaining to meetings call the secretary.

NORTH TEXAS GEOLOGICAL SOCIETY
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Consulting Geologist
First National Bank Building

Vice-President - - - - - - A. W. Weeks
Shell Petroleum Corporation

Secretary-Treasurer - - - John T. Sanford
Magnolia Petroleum

Meetings: Second Friday, each month, at 6:30 P.M.
Luncheons: Fourth Friday, each month, at 12:15 P.M.
Place: Hamilton Building

EAST TEXAS GEOLOGICAL SOCIETY
TYLER, TEXAS

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Vice-President - - - - Robert B. Mitchell
Stanolind Oil and Gas Company

Secretary-Treasurer - - - Robert L. Jones
Empire Gas and Fuel Company

Meetings: Monthly and by call.

Luncheons: Every Friday, Cameron's Cafeteria.

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Amerada Petroleum Corporation, Midland

Meetings will be announced

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Secretary-Treasurer - - - Stuart Mossom
Magnolia Petroleum Company, San Antonio

Executive Committee - - - Adolph Dovre and C. C. Miller

Meetings: Third Monday of each month at 8 P.M. at the Petroleum Club. Luncheons every Monday noon except third Monday of month at Peroleum Club, Alamo National Building.

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401 Union Building

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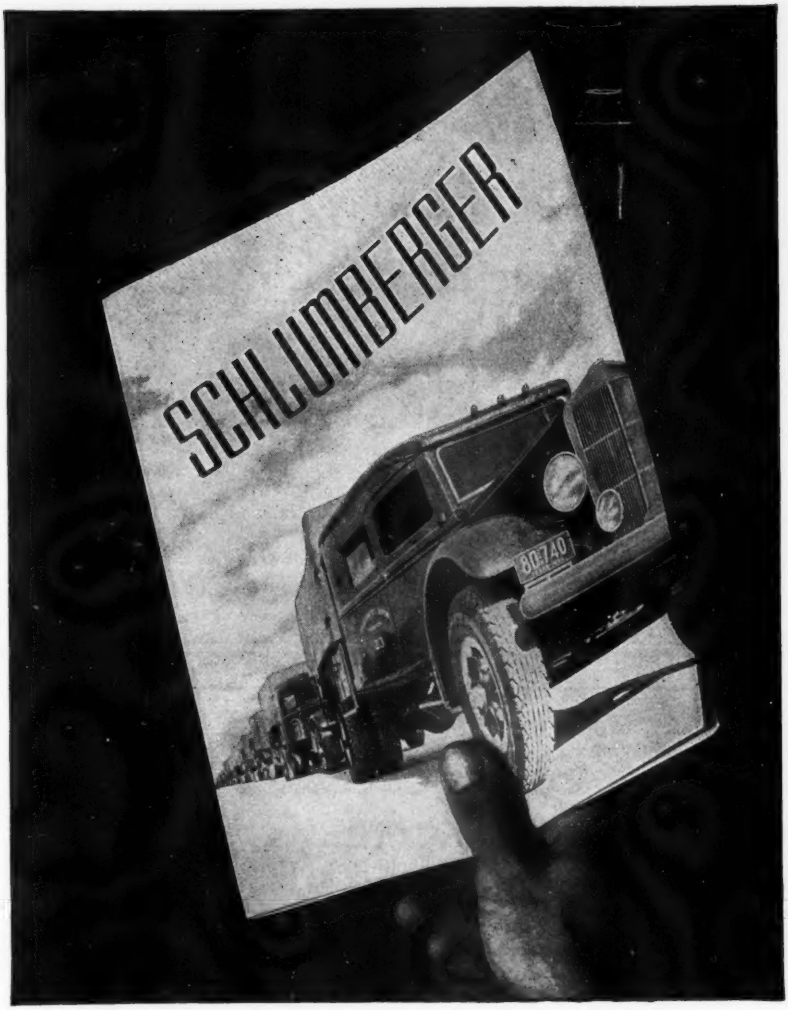
Consulting Geologist and Producer
Second National Bank Building,
Ashland, Kentucky

Secretary-Treasurer - - - Charles Brewer, Jr.
Godfrey L. Cabot, Inc., Box 348

Meetings: Second Monday, each month, at 6:30 P.M., Ruffner Hotel.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